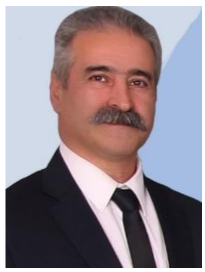
Author: Prof. Abdolreza Shahrabi Farahani

The Owner of the Philosophy and Theory of Principles of Mechanic Time

The Owner of the Philosophy of Subjective Physics Sciences



Author's Senior Advisor: Prof. Seyed Vahab Mirsalehi

Philosophy of Kant and Nietzsche - Oriental Sciences and Philosophy

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PART II: SCIENTISTS

About Leonardo da Vinci.

Leonardo da Vinci, full name Leonardo di ser Piero da Vinci, was one of the greatest Italian artists, inventors, engineers, scientists, and writers of the Renaissance period. He was born on April 15, 1452, in the town of Vinci in Tuscany, Italy, and passed away on May 2, 1519, in France.

Da Vinci was active in a wide range of artistic, scientific, philosophical, and technical fields. Among his artistic works, one can mention masterpieces such as the Mona Lisa, The Last Supper, The Birth of Venus, and The Madonnas.

He also worked in various areas such as engineering, natural sciences, anatomy, physiology, philosophy, poetry, and writing.

Da Vinci was one of the most versatile and complete individuals who is known as a genius due to his vast knowledge and information in various fields.

He is famous for many of his scientific inventions and discoveries, such as the invention of flying machines, the analysis of human anatomy, the study of water currents, the creation of the first visual code of the world, the creation of the first steam engine, and the design of military and defense devices.

He was one of the prominent intellectuals of the Renaissance period and had a significant impact on art, science, and technology worldwide. Therefore, Da Vinci is known as one of the prominent figures in the history of Italy and the world.

In addition to art, Da Vinci was active in various fields. He is famous as an engineer, inventor, scientist, anatomist, physiologist, philosopher, and writer.

In the field of engineering, Da Vinci actively worked on designing and building various devices, including military devices, flying machines, mining machines, and advanced agricultural machines. Many of these inventions were not built during Da Vinci's time, but many of his ideas were developed in later periods.

In the field of science, Da Vinci studied and researched nature and the world in detail. He is known as an anatomist and physiologist and carried out detailed studies of the structure of the human and animal bodies. He also conducted research in the fields of physics, chemistry, and mathematics.

Da Vinci also worked actively as a writer and poet. He wrote about poetry, philosophy, and humanities. Some of his works include the "Notebook of Middle Notes" (Codex Cryptex), "Anatomy Notebook," "Technical Articles Notebook," and "Poetry Notebook."

Da Vinci's work was extensive and varied and included artistic, scientific, technical, engineering, and philosophical fields.

The following are some of his prominent works:

1. Art:

1.1) Painting of the Mona Lisa

1.2) Painting of The Last Supper

1.3) Painting of The Birth of Venus

1.4) Painting of The Madonnas

2. Engineering and Technical:

2.1) Design and construction of military and defense devices

2.2) Design of the hydraulic lift device

2.3) Design and construction of flying machines

2.4) Design and construction of mining machines.

3. Science:

3.1) Study and research on human and animal anatomy

3.2) Study of water and wind currents

3.3) Research and study of physics, chemistry, and mathematics

3.4) Analysis of animal behavior and movement

4. Philosophy:

4.1) Study and analysis of philosophical and scientific concepts

4.2) Writing about philosophy and humanities

This categorization is just a few examples of Da Vinci's masterpieces, and he had many other inventions, discoveries, and artistic works.

The painting of the Mona Lisa, also known as "La Gioconda," is one of the world's unparalleled artistic masterpieces created by Leonardo da Vinci. This painting is kept in the Louvre Museum in Paris, France, and has gained the most attention and popularity among all the world's artworks.

The painting of the Mona Lisa is a color portrait of a young woman with a subtle smile, slightly curved eyes, and a green veil over her shoulders. The painting shows her half-body facing the viewer, with a background of a cityscape with bridges, canals, and distant mountains.

The greatest attraction of the painting is the expression of human qualities in Mona Lisa's enigmatic smile, which is recognized as one of the most prominent artistic symbols in the world. Leonardo da Vinci used innovative artistic techniques to create this painting. He used a technique called "sfumato" which combines dark and light colors to achieve precise results.

The Mona Lisa painting is not only recognized as a masterpiece of art but also as a symbol of beauty, spirituality, dynamism, and mystery for its viewers. For many artists and researchers, this painting has been inspirational as an example of combining art and science and is still one of the most famous and beloved works in the history of art.

The painting of the Mona Lisa has become one of the most famous and well-known works of art in the world for various reasons.

Some of the main reasons for its fame are:

Innovative Artistic Techniques: Leonardo da Vinci used innovative artistic techniques to create the Mona Lisa painting. He combined dark and light colors to achieve precise results. These innovative artistic techniques were very new and innovative for that time and were recognized as a masterpiece of art.

Attractiveness of Mona Lisa's Face: The portrait of the young woman in the Mona Lisa painting with a subtle smile and slightly curved eyes is fascinating to viewers. The attractiveness of Mona Lisa's face is recognized as one of the most prominent artistic symbols in the world.

Extraordinary Fame of the Painting: The Mona Lisa painting is recognized as a unique masterpiece of art and has gained the most attention and popularity among all the world's artworks. Also, its transformation into one of the cultural and historical symbols in the world is another reason that has turned it into one of the most famous works of art.

Secrets and Mysteries of the Painting: The Mona Lisa painting is recognized as one of the most mysterious and fascinating paintings due to the presence of various secrets and mysteries, such as the enigmatic smile and an ambiguous background. These secrets and mysteries are recognized as one of the significant reasons for the painting's attractiveness and popularity in the world of art and culture.

Due to these reasons, the painting of Mona Lisa has become one of the most famous and recognized works of art in the world, which is still on display at the Louvre Museum in Paris, France, and attracts many visitors from all over the world every year.

There are various secrets and mysteries in the Mona Lisa painting that have been examined by researchers and artists, but none of these secrets have been officially confirmed and many of them remain only myths.

One of the well-known mysteries in the Mona Lisa painting is the enigmatic smile of the woman in the painting.

Some researchers believe that Mona Lisa's smile is a sign of deception and trickery, while others believe that her smile represents romantic feelings.

None of these interpretations have been officially confirmed and both of them are recognized as one of the hidden mysteries of the Mona Lisa painting.

Another mystery mentioned is the vague background in the painting. Some researchers believe that the background of the painting, which includes distant cityscapes and mountains, is exactly aligned with the planetary mapping in the northern geographical direction. However, this interpretation has not been officially confirmed either.

The secrets and mysteries of the Mona Lisa painting are still the subject of discussion and debate among art and history researchers, and they have never been officially confirmed or even denied.

However, this ambiguity and enigma surrounding the painting has made many people more interested in it and recognized it as one of the world's unique artistic masterpieces.

"The Last Supper" painting is a great work created by Leonardo da Vinci. This painting depicts the last supper of Jesus and his twelve disciples.

The painting was painted on a wall in the Santa Maria or Milan church in northern Italy.

"The Last Supper" painting is one of the greatest artistic masterpieces in the world and is recognized as one of the most prominent artistic symbols in the world. For its creation, da Vinci used innovative artistic techniques and through the use of bright and dark colors, he portrayed the movement and psyche of the painting's characters.

Da Vinci conducted extensive research on the Last Supper of Jesus and the available descriptions of it before creating this painting. Then, using techniques such as portraiture, proportionality, and attention to light and shadow, he portrayed the characters of the painting.

In "The Last Supper" painting, Jesus is seated in the middle, and his twelve disciples are grouped in pairs of three on either side of him. Among these twelve disciples, one of them has become known as the infamous traitor who is positioned next to Jesus in the painting.

Additionally, in "The Last Supper" painting, da Vinci used innovative artistic techniques and through attention to light and shadow, he portrayed the movement and psyche of the painting's characters. For example, the use of light and shadow behind the painting's characters helped portray their movement and psyche.

"The Last Supper" painting is recognized as one of the world's unique artistic masterpieces due to the use of innovative artistic techniques and attention to detail. It is still recognized as one of the most important and fascinating works of art in history.

Da Vinci created "The Last Supper" painting in the 1490s. Most sources consider the creation of this painting to be in the year 1495. The painting is located on a wall in the Santa Maria delle Grazie or Milan church in northern Italy and is still on display there.

Indeed, "The Last Supper" painting is believed by many researchers and artists to have hidden secrets and mysteries that are still being pursued.

One of the well-known secrets in this painting is a combination of geometric shapes and various symbols that were used in the painting, which is likely a sign of da Vinci's scientific and philosophical connections to various subjects such as mathematics, philosophy, and natural science.

Moreover, some researchers believe that in "The Last Supper" painting, da Vinci used portraiture and symbolism to connect various characters and establish relationships between them, which is recognized as one of the painting's secrets.

The secrets and mysteries of "The Last Supper" painting are still the subject of discussion and debate among artists and researchers, and many of them remain a puzzle for many people.

However, as mentioned earlier, some of the secrets and symbols in this painting have been identified, and further analysis is still ongoing.

In "The Last Supper" painting, other symbols have also been used, and I will mention some of them below:

Geometric shapes: In "The Last Supper" painting, da Vinci used various geometric shapes such as triangles, squares, and circles, which may be a sign of his scientific and philosophical connections to various subjects such as mathematics and philosophy.

Direction of characters: The characters in the painting are placed in various directions, which can refer to a combined and relational concept.

Attention to details: Da Vinci paid attention to many details in "The Last Supper" painting, to the point that each character is described briefly with specific details. For example, some characters have movements and gestures that indicate the psychology and reality in the painting.

Light and shadow: Da Vinci used the technique of light and shadow in "The Last Supper" painting to give movement and liveliness to the characters.

Colors: In "The Last Supper" painting, da Vinci used bright and dark colors to give volume and depth to the characters.

Symbols: In "The Last Supper" painting, da Vinci used various symbols such as a sinister symbol that refers to the traitor.

As can be seen, "The Last Supper" painting has many artistic details and symbols, which have led artists and researchers to seek the discovery of its mysteries. "The Madman" painting is one of the famous works of Leonardo da Vinci, which is kept in the National Exhibition of Monte Carlo in Monaco. This painting depicts a character sitting on a rock while looking at his two hands.

In "The Madman" painting, Da Vinci has tried to show the character of the madman in a way that really seems like he is diving into his own world while looking at his hands, using lighting and special techniques. Some artists and researchers recognize this painting as one of the works that reflects Da Vinci's mental state in some periods of his life.

In terms of color, "The Madman" painting is depicted with simplicity and mostly portrays the realistic character. However, this painting has succeeded in creating a sense of despair and mystery around the character of the madman, creating a halo of mystery and secrets around him and causing some researchers and artists to seek the discovery of the concept and importance of this character in the painting.

"The Madman" painting, as one of the famous works of Leonardo da Vinci, portrays a character who has tried to display his mental state in a way that may be associated with the experiences of others, using special lighting and techniques.

Leonardo da Vinci, in addition to being an artist, was also one of the prominent scholars of the Renaissance era. He was active in various scientific fields, including mathematics, geometry, philosophy, and physical sciences.

For example, Da Vinci was educated in archaeology and geology, and some of his works in the field of astronomy and physiology are also known.

In the field of mathematics, Da Vinci was educated as one of the students of Eugenio D'Ovidio, one of the greatest mathematicians of the Renaissance era.

He was interested in studying and researching in the field of geometry and three-dimensional spaces. In particular, Da Vinci was interested in studying curved spaces and conducted extensive research in this field.

He was skilled in using mathematical methods to describe shapes and objects in his artworks. For example, in "The Last Supper" painting, he used various geometric shapes such as triangles, squares, and circles, which can also be seen in other artworks such as "St. John the Baptist".

Leonardo da Vinci, as one of the prominent artists and scholars of the Renaissance era, was interested in studying and researching various scientific fields, including mathematics and geometry, and he used mathematical methods to describe shapes and objects in his artworks.

Da Vinci conducted extensive research on curved spaces. He was interested in examining three-dimensional curved spaces and analyzing and describing these spaces. For example, in his notebooks, Da Vinci studied problems such as identifying whether a surface is curved or not, describing curved spaces based on the number of their curves, and analyzing the differentiation of curved spaces using concepts such as tangent and control of the elliptical section.

One of Da Vinci's famous researches in the field of curved spaces was related to topology. He studied assumptions about topology and examined their effects on various geometric shapes. Additionally, Da Vinci conducted research on curved coverings and described them using analytical changes in their various shapes.

Da Vinci conducted extensive research on three-dimensional curved spaces, focusing on topology and geometry. These researches are recognized as one of his most important scientific legacies, demonstrating that Da Vinci was interested in learning and researching in various scientific fields as one of the prominent scholars of the Renaissance era.

Leonardo da Vinci was active in various scientific fields, including mathematics and geometry. In the field of trigonometry, Da Vinci conducted extensive research and attempted to examine the various laws and relationships that exist in relation to triangles.

One of Da Vinci's studies in the field of trigonometry was the examination of different ratios in triangles. For example, he studied the ratio of the lengths of the different sides of a triangle and the ratio of the perimeter of a triangle. He also examined the triangle properties such as the median, mode, and median of a triangle.

Da Vinci was interested in examining trigonometric laws such as the Pythagorean theorem and the sine and cosine laws. He also studied the different shapes that could be created through the combination of these laws.

Da Vinci was interested in researching and studying various scientific fields, including trigonometry. By examining the different laws and relationships of trigonometry, he attempted to investigate and explain them. These researches are recognized as one of his scientific legacies.

Da Vinci also studied trigonometry in three-dimensional space.

Da Vinci was interested in analyzing and examining trigonometry in three-dimensional spaces and studied some of the laws and relationships of trigonometry in these spaces.

For example, in one of Da Vinci's paintings called "Vitruvian Man," he used trigonometry in three-dimensional space. In this painting, Da Vinci examined the different ratios that exist in spatial triangles.

Da Vinci also studied the trigonometric properties in three-dimensional space. For example, he studied the medians and averages of spatial triangles and examined the relationships between various parameters of spatial triangles such as their area and volume.

Da Vinci was interested in analyzing and explaining these relationships and laws in various fields, including three-dimensional spaces.

During the Renaissance era, Da Vinci was interested not only in art but also in science and technology. He was also involved in designing and building military and defense devices and analyzed issues such as explosives, weapons, and defense systems.

Regarding the design and construction of military devices, Da Vinci was interested in designing and building weapons such as flamethrowers and land mines.

He studied explosives and their production methods and tried to find ways to improve the efficiency and power of these weapons.

Da Vinci was also interested in designing and building defense systems. In this field, he studied defensive structures such as high walls, castles, and watchtowers and tried to find ways to improve their efficiency.

Da Vinci was interested in research and design in the field of military and defense devices. He studied issues such as explosives, weapons, and defense systems and tried to find ways to improve the efficiency and practicality of these devices.

Da Vinci was interested in designing various devices. One of the devices he designed was a water-lifting device, which was created to move water from a lower area to a higher area.

This device consisted of a water-lifting system with two absorbers, which, with the help of wire drawing and a combination of gear mechanisms and gear wheels, transferred water to the highest point.

The main goal of this device was to increase efficiency in water transportation and was used in agriculture and irrigation.

In designing this device, Da Vinci studied the hydraulic properties of water in its natural movement and tried to improve the performance of this device. Using his knowledge in mechanics and hydraulics, he tried to improve the performance of this device.

Da Vinci was interested in designing various devices, and the water-lifting device was one of the designs he created. He proposed improvements in the performance of this device using his knowledge in mechanics and hydraulics, and he is considered one of the pioneers in industrial developments.

With an interest in flight and birds, Da Vinci was also interested in designing and building flying machines. In the field of designing flying machines, he studied and analyzed bird flight and tried to find ways to simulate and improve the flight of flying machines.

One of the most important bird-like designs that Da Vinci created was a flying machine that was designed based on the study of bird flight.

The model had a wing structure similar to that of a glider and a body that was similar to that of a human. In this model, Da Vinci used elements such as larger and more significant wings, a wing and tail control system, and a balance system.

Moreover, Da Vinci studied and analyzed the structure of birds and examined the physical characteristics of birds such as body shape, wings, tail, and feathers. He was trying to find solutions to improve the performance of flying machines.

Da Vinci was interested in designing and building flying machines and improving their performance by studying and analyzing bird flight. He is considered one of the pioneers in industrial and aviation developments.

During the Renaissance period, Da Vinci was interested in designing and building various devices in different fields, including mining industries. One of the devices he designed was a mining cutting machine.

This device consisted of a mining cutting system with a gear that worked using water energy. The main goal of this device was to facilitate and improve the mining cutting process.

In designing this device, Da Vinci studied the characteristics of mines and rocks and tried to find ways to improve the efficiency and practicality of these machines. One of the advantages of this device was the improvement in the efficiency and quality of mining cutting.

Da Vinci also studied and analyzed the structure of rocks and mines and examined their physical characteristics. He was trying to find solutions to improve the performance of mining cutting machines.

Da Vinci was interested in designing and building various devices in different fields, including mining industries, and the mining cutting machine was one of the designs he created. By studying and analyzing the structure of rocks and mines, he proposed improvements in the performance of this device and is considered one of the pioneers in industrial developments.

Da Vinci conducted extensive research on water and wind flows and tried to find ways to improve the performance of machines such as elevators, water pumps, boats, and sails by studying and analyzing water and wind flows.

Regarding water flow, Da Vinci studied the characteristics of water flow in rivers, seas, and other water sources and tried to find ways to improve the performance of machines such as water pumps and water elevators. By studying and analyzing the characteristics of water flow, he was trying to find solutions to improve the performance of these machines.

Regarding wind flow, Da Vinci studied the characteristics of wind flow and tried to find ways to improve the performance of machines such as sails and boats.

He studied and analyzed the structure of sails and the systems that use wind energy and tried to find ways to improve the efficiency and practicality of these machines.

Da Vinci was interested in studying and analyzing water and wind flows and tried to find ways to improve the performance of machines such as elevators, water pumps, boats, and sails by studying and analyzing the characteristics of water and wind flows. He is considered one of the pioneers in industrial developments.

Da Vinci was also interested in studying and analyzing the behavior and movement of animals. He studied and analyzed the movements of animals and tried to find ways to improve the performance of machines such as robots and mechanical devices.

Regarding animal movements, Da Vinci studied and analyzed the movement characteristics of animals such as birds, reptiles, fish, and other animals and tried to find ways to improve the performance of machines such as robots and mechanical devices.

He was trying to find solutions to improve the performance of these machines by studying and analyzing the movement characteristics of animals.

In addition to studying animal movements, Da Vinci also analyzed animal behavior.

He investigated the behavior of animals in natural environments and their effects on the behavior and performance of other animals.

Da Vinci attempted to find ways to improve the performance of machines such as robots and mechanical devices by studying and analyzing the movements and behaviors of animals. He is considered a pioneer in the field of industrial development due to his studies of the motion and behavior of animals.

Da Vinci was also interested in physics, chemistry, and mathematics. He analyzed the principles and fundamental laws in these fields and attempted to find ways to improve the performance of scientific and industrial devices.

Regarding physics, Da Vinci investigated the laws of motion and force and sought solutions to improve the performance of physical devices such as telescopes, elevators, and military devices.

By analyzing the physical properties of these devices, he sought ways to improve their efficiency and functionality.

Regarding chemistry, Da Vinci analyzed the properties and behaviors of chemical elements and attempted to find ways to improve the performance of chemical devices such as laboratory tubes and chemical production machinery.

By analyzing the chemical properties of these devices, he sought ways to improve their efficiency and functionality.

In mathematics, Da Vinci studied and analyzed the principles and laws of mathematics and attempted to find ways to improve the performance of mathematical devices such as calculators and military devices.

By analyzing the mathematical properties of these devices, he sought ways to improve their efficiency and functionality.

Da Vinci was interested in studying and researching physics, chemistry, and mathematics and attempted to find ways to improve the performance of scientific and industrial devices. By analyzing the physical, chemical, and mathematical properties, he is considered a pioneer in the field of industrial development.

Da Vinci was also interested in studying and researching human and animal anatomy. He analyzed the structure of the human and animal body and attempted to find ways to improve the performance of medical and military devices.

Regarding human anatomy, Da Vinci analyzed the internal structure of the human body including bones, muscles, veins, and other organs. He attempted to find solutions to improve the performance of medical devices such as surgical instruments, diagnostic tools, and other medical devices. By analyzing the anatomical properties of the human body, he sought ways to improve the performance and efficiency of these devices.

In regards to animal anatomy, Da Vinci analyzed the structure of animal bodies including bones, muscles, veins, and other organs. He attempted to find solutions to improve the performance of military devices such as weapons, transportation devices, and other military devices. By analyzing the anatomical properties of animals, he sought ways to improve the performance and efficiency of these devices.

Da Vinci was interested in studying and researching both human and animal anatomy and attempted to find ways to improve the performance of medical and military devices.

By analyzing the anatomical properties of both humans and animals, he is considered a pioneer in the field of scientific and medical development.

Leonardo da Vinci was active in various fields including philosophy and science. He analyzed and explored philosophical and scientific concepts and expressed his own views in these fields.

Leonardo da Vinci explored various philosophical issues, such as the meaning of life, human nature, and the concept of intelligence. He presented innovative perspectives on the concept of intelligence, suggesting that intelligence is a multifaceted attribute that includes various skills such as thinking, creativity, memory, and cognition.

As one of the greatest scientists in history, Da Vinci researched and studied various fields such as mathematics, physics, chemistry, and anatomy. He analyzed and explored scientific and research methods and presented innovative perspectives in these areas, achieving great success in his work.

Da Vinci also explored the concept of human nature and the role of humans in the world. By analyzing and studying the structure of the human and animal body, he sought solutions to improve the performance of medical and military devices.

As one of the greatest innovators in history, Da Vinci utilized innovative thinking to come up with creative and novel solutions to complex problems. His innovative thinking led him to develop groundbreaking ideas that have since influenced various fields of study.

Da Vinci explored and analyzed various philosophical and scientific concepts and presented his own perspectives on these issues.

He is recognized as one of the greatest representatives of the Renaissance period in various fields such as art, science, engineering, philosophy, and literature and is considered a pioneer in these areas in history.

Da Vinci had a wide range of activities in various fields, including philosophy and humanities. Throughout his life, he examined and analyzed various philosophical and human concepts and expressed his perspectives on these issues.

In the following, some of the philosophical and human concepts explored by Da Vinci are explained:

Philosophy: Da Vinci explored various philosophical issues. He examined the meaning of life, human nature, and the concept of intelligence.

For example, he presented an innovative perspective on the concept of intelligence, suggesting that intelligence is a multifaceted attribute that includes various skills such as thinking, creativity, memory, and cognition.

Humanities: Da Vinci explored concepts such as human behavior, human nature, and the role of humans in the world. He examined and analyzed the structure of the human and animal body, searching for solutions to improve the performance of medical and military devices.

In fact, Da Vinci is known as one of the pioneers in humanities.

Ethics: Da Vinci focused on examining ethical issues and sought to provide a precise analysis of these issues. He explored concepts such as good and evil and justice, searching for solutions to enhance ethics and human values.

Culture: Da Vinci examined issues related to culture and art. By analyzing concepts such as beauty and art, he sought to find solutions to develop art and culture.

Da Vinci explored and analyzed various philosophical and human concepts and presented his own perspectives on these issues.

He is recognized as one of the greatest representatives of the Renaissance period in various fields such as art, science, engineering, philosophy, and literature and is considered a pioneer in these areas in history.

Leonardo da Vinci is recognized as one of the pioneers in various fields:

Art: Da Vinci is known as one of the most prominent artists in history. He is famous for his paintings such as the Mona Lisa and The Last Supper.

Science: Da Vinci is known as one of the prominent scientists of the Renaissance period, in fields such as mathematics, physics, chemistry, anatomy, and the study and analysis of natural phenomena as a pioneer.

Engineering: Da Vinci is known as one of the greatest engineers in history. He was involved in designing tools and devices such as drone wings, military equipment, and medical devices.

Philosophy: Da Vinci is known as one of the most prominent philosophers in history. He delved into issues such as the meaning of life, human nature, and the concept of intelligence.

Literature: Da Vinci is known as one of the greatest writers in history. He was engaged in writing manuscripts such as "Anatomy Notebooks", "Drawing Notebooks", and "Scientific Notebooks".

Da Vinci is recognized as a pioneer in various fields such as art, science, engineering, philosophy, and literature, and is considered one of the greatest representatives of the Renaissance period in world history.

About Abu Ali al-Hasan ibn al-Hasan ibn al-Haytham al-Basri

Abu Ali Muhammad ibn Hasan ibn al-Haytham al-Basri, known as "Al-Hasan ibn al-Haytham," was a prominent figure in mathematics, physics, and other sciences. He was born in 965 AD in the city of Basra, Iraq. Al-Hasan ibn al-Haytham is known as the "Father of Optics" or the "Arab Newton" for his scientific work and numerous discoveries.

He worked in various fields such as mathematics, physics, optics, humanities, philosophy, and natural sciences. Some of his important contributions in physics include his research on the reflection and refraction of light in the eye, the discovery of the law of light refraction in different media, and the discovery of the law of light refraction in conical lenses.

He also worked in the field of mathematics and contributed to many mathematical topics such as geometry, algebra, combinatorics, and computation.

One of his important works in this field is the book "Al-Munazar fi al-Hisab" which is known for analytical geometry.

Al-Hasan ibn al-Haytham lived until 1039 AD and passed away in Baghdad in that year. He provided the basis and foundation for many sciences that later developed, and is known as one of the greats in the scientific world.

Al-Hasan ibn al-Haytham worked in various fields such as optics, humanities, philosophy, and natural sciences, and made many important scientific discoveries. One of his important works in the field of optics was the discovery of the rule of image formation in the eye and how images are formed on the retina. This discovery is widely used in many fields of medicine and information technology.

In the field of philosophy and humanities, Al-Hasan ibn al-Haytham studied the concept of vision and sight, and presented various theories in this regard. He also explored issues such as the concept of experience, knowledge, and dreaming.

In the field of natural sciences, Al-Hasan ibn al-Haytham presented new laws about the motion and fall of objects and studied the effect of size and weight on the movement of objects. He also studied the process of rain formation and clouds and presented new theories about the formation of clouds and rain, which are very important discoveries for many sciences related to weather and agriculture.

Al-Hasan ibn al-Haytham was one of the most prominent scientists in history who contributed to the development of science and knowledge and the advancement of humanity in many scientific and cultural fields.

Al-Hasan ibn al-Haytham was born in the city of Basra, Iraq and was not directly Iranian. However, he was influenced by the culture and science of ancient Iran during his scientific period and benefited from the prominent works of Iranians in the fields of mathematics and natural sciences.

On the other hand, he was also a place of influence and scientific and cultural activity during the Islamic period in Iran. Therefore, he can be considered as one of the prominent Islamic and Iranian scientists who contributed to the development of science and knowledge in the Muslim world and the world.

Available information indicates that Al-Hasan ibn al-Haytham is mentioned in some sources about teaching in Isfahan, but this issue is still under debate and requires accuracy. Some historical Muslim sources, including the book "Al-Fihrist" by Ibn Nadim and "Tarikh al-Hukama" by Ibn al-Qayyim, claim that Al-Hasan ibn al-Haytham taught some of his lessons in Isfahan. However, this matter is still under discussion and investigation, and it cannot be confirmed with certainty.

Although Al-Hasan ibn al-Haytham has a special place in the history of Islamic science and knowledge, more investigation and discussion are still needed about his teachings in Isfahan.

Indeed, Al-Hasan ibn al-Haytham was involved in various scientific and cultural activities and had significant contributions in several fields:

In the field of optics, Al-Hasan ibn al-Haytham presented the law of light refraction in different media and the law of light refraction in conical lenses.

In the field of mathematics, he studied subjects such as geometry, algebra, combinatorics, and calculus and wrote a book called "Al-Munathara fi al-Handasa" about analytical geometry.

In the field of natural sciences, Al-Hasan ibn al-Haytham studied the process of rain and cloud formation and presented new theories about the formation of clouds and rain.

In the field of humanities, he studied the concept of vision and sight and presented various theories in this regard. He also explored issues such as the concept of experience, knowledge, and dreaming.

Al-Hasan ibn al-Haytham also studied philosophical issues such as the problem of existence, thinking, and anthropology.

He studied issues related to the motion and fall of objects and the effect of size and weight on the movement of objects.

Al-Hasan ibn al-Haytham wrote many other books on various subjects, including medicine, philosophy, and social sciences.

Overall, Al-Hasan ibn al-Haytham was a multi-talented and versatile scholar who contributed significantly to the advancement of science and knowledge in various fields.

Indeed, Al-Hasan ibn al-Haytham was one of the most prominent scientists in history, who contributed significantly to the development of science and knowledge in the Muslim world and the world.

He studied and developed various laws and concepts related to optics, which are widely used in science and technology:

Law of light refraction: Al-Hasan ibn al-Haytham discovered the law of light refraction in different media. He studied how light bends due to changes in intensity and direction in various media.

Law of light refraction in conical lenses: Al-Hasan ibn al-Haytham presented the law of light refraction in conical lenses. This law is of great importance in the development of lens technology and imaging devices.

Correct vision: Al-Hasan ibn al-Haytham studied the concept of correct vision and presented new theories about how images are formed on the retina. These theories have helped many fields, including medicine and information technology.

Overall, Al-Hasan ibn al-Haytham's contributions in the field of optics were significant and laid the foundation for many advancements and developments in science and technology.

Light vibrations: Al-Hasan ibn al-Haytham studied light vibrations and presented new theories on this subject. These theories have helped many fields, including physics of light, lighting, and optics.

Wave refraction: Al-Hasan ibn al-Haytham studied subjects such as wave refraction and presented new theories on this subject. These theories have helped many fields, including physics and electronic engineering.

Al-Hasan ibn al-Haytham also studied how images are formed in imaging devices. He explored the concept of correct vision and presented new theories on how images are formed on the

retina and in imaging devices. These theories have helped many fields, including medicine and information technology.

Al-Hasan ibn al-Haytham paid close attention to the concept of imaging and studied how images are formed in the human mind and how they are displayed in various imaging devices.

He explored concepts such as correct vision and light vibrations and presented new theories on how images are formed in imaging devices such as cameras and telescopes.

Indeed, Al-Hasan ibn al-Haytham studied the concepts of light reflection and refraction and presented new theories in this field. His theories and research have helped many fields, including pharmaceutical science, medical physics, and medical imaging.

In the field of mathematics, Al-Hasan ibn al-Haytham also studied various problems that are widely used in science and technology:

Geometry: Al-Hasan ibn al-Haytham developed new theories in the field of geometry. He studied issues such as the theory of elasticity, analytical geometry, and geometric logic and wrote the book "Al-Munathara fi al-Hindasa" on analytical geometry.

Algebra: Al-Hasan ibn al-Haytham studied various problems in the field of algebra. He explored concepts such as combinatorics, differential equations, and linear algebra and presented new theories on these issues.

Combinatorics: Al-Hasan ibn al-Haytham also studied combinatorial problems.

He explored issues such as permutation and combination and presented new theories in this regard.

Overall, Al-Hasan ibn al-Haytham's contributions in the field of mathematics were significant and laid the foundation for many advancements and developments in science and technology.

Calculations: Al-Hasan Ibn al-Haytham also dealt with mathematical problems. He investigated issues such as the problem of dividing areas and the problem of intersecting lines.

Number theory: Al-Hasan Ibn al-Haytham also researched various issues in the field of number theory. He investigated topics such as prime numbers, composite numbers, and Diophantine equations.

Al-Hasan Ibn al-Haytham contributed greatly to the development and expansion of knowledge in the field of mathematics and became one of the most prominent scientists in this field.

He developed new theories in various areas such as geometry, algebra, and combinatorics, and accompanied many developments in this field.

Al-Hasan Ibn al-Haytham also investigated various issues in the fields of algebra and geometry.

Geometry: Al-Hasan Ibn al-Haytham developed new theories in the field of geometry. He investigated issues such as the theory of elasticity, analytical geometry, and geometric logic, and wrote the book "Al-Mandhur fi al-Hendasa" on analytical geometry. He also developed methods for solving geometric

problems using different concepts such as points, lines, and circles.

Algebra: Al-Hasan Ibn al-Haytham investigated various issues in the field of algebra. He studied different concepts such as combinatorics, differential equations, and linear algebra, and presented new theories on these topics. He developed methods for solving equations and algebraic problems and used algebraic principles to solve geometric problems.

Geometric problems using algebra: Al-Hasan Ibn al-Haytham developed methods for solving geometric problems using algebra. He investigated issues such as the problem of dividing areas and the problem of intersecting lines, and used algebraic principles to solve these problems.

Combinatorics: Al-Hasan Ibn al-Haytham also studied combinatorial problems. He investigated issues such as permutations and combinations and used combinatorial principles to solve geometric and algebraic problems.

Geometry: Al-Hasan Ibn al-Haytham developed new theories in the field of geometry. He investigated issues such as the theory of elasticity, analytical geometry, and geometric logic, and wrote the book "Al-Mandhur fi al-Hendasa" on analytical geometry. He also developed methods for solving geometric problems using different concepts such as points, lines, and circles.

Algebra: Al-Hasan Ibn al-Haytham investigated various issues in the field of algebra. He studied different concepts such as combinatorics, differential equations, and linear algebra, and presented new theories on these topics.

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Geometric problems using algebra: Al-Hasan Ibn al-Haytham developed methods for solving geometric problems using algebra. He investigated issues such as the problem of dividing areas and the problem of intersecting lines, and used algebraic principles to solve these problems.

Combinatorics: Al-Hasan Ibn al-Haytham also studied combinatorial problems. He investigated issues such as permutations and combinations and used combinatorial principles to solve geometric and algebraic problems.

Al-Hasan Ibn al-Haytham contributed greatly to the development and expansion of knowledge in the fields of algebra and geometry, and became one of the prominent scientists in these fields. He developed new theories on various issues such as geometry, algebra, and combinatorics, and accompanied many developments in these fields.

The book "Al-Manazir fi al-Hendasa" is one of the most important scientific works of Al-Hasan Ibn al-Haytham in the fields of geometry and optics. This book was written in Arabic for the first time in the 10th century AD.

In this book, Al-Hasan Ibn al-Haytham discusses various issues in the fields of optics and geometry. He uses geometric methods to explain various concepts such as the flexibility of light, the refraction of light in lenses, and the formation of images in imaging devices.

In this book, Al-Hasan Ibn al-Haytham presents new methods for examining images and light, and new theories on the formation of images in the retina of the eye and imaging devices. He discusses concepts such as correct vision, light vibrations, and the theory of flexibility, and uses geometric principles to solve optical problems.

This book was recognized as one of the primary foundations of light physics and optics during the medieval period, and afterwards was known as one of the most important works in the field of physics and optics in history.

Additionally, this book is still recognized as one of the prominent works in the fields of geometry and mathematics for researchers and scientists.

Al-Hasan Ibn al-Haytham investigated various issues in the fields of combinatorics and calculations:

Combinatorics: Al-Hasan Ibn al-Haytham explored combinatorial issues. He studied problems such as ordering and various combinations. In particular, he studied the problem of queueing and presented new methods for solving the problem.

Calculations: Al-Hasan Ibn al-Haytham examined computational problems. He studied problems such as calculating the area and volume of various points in space, and presented new methods for solving these problems.

Algebra: Al-Hasan Ibn al-Haytham explored algebraic concepts such as different definitions for sets, operations, numbers, and equations. He developed new theories in the field of algebra and used methods to solve algebraic problems.

Solving Geometric Problems Using Algebra: Al-Hasan Ibn al-Haytham used methods to solve geometric problems using algebra. He studied problems such as the problem of dividing areas and the problem of intersecting lines, and used algebraic principles to solve these problems.

Al-Hasan Ibn al-Haytham was a great philosopher who was active in many fields of knowledge, including philosophy. He helped to develop and expand philosophical knowledge and presented new theories in this field:

Logic: Al-Hasan Ibn al-Haytham studied logical concepts such as decision-making, reasoning, and inference. He developed new theories about logic and used new methods to solve logical problems.

Philosophy of Science: Al-Hasan Ibn al-Haytham studied philosophical concepts such as the nature of science, scientific method, the dependence of science on experience, and how to investigate and interpret information. He developed new theories about the philosophy of science and used new methods to develop scientific knowledge.

Philosophy of Religion: Al-Hasan Ibn al-Haytham studied philosophical concepts such as the concept of God, the concept of prophecy, and the interpretation of religious concepts. He developed new theories about the philosophy of religion and used new methods to investigate and interpret religious concepts.

Worldview: Al-Hasan Ibn al-Haytham studied philosophical concepts such as worldview and how humans think.

He developed new theories about worldview and human thinking and used new methods to analyze and investigate human worldview.

Al-Hasan Ibn al-Haytham contributed greatly to the development of philosophy and is known as one of the prominent philosophers in history. He made many developments in the field of philosophy and developed new theories on various issues, contributing greatly to the development of philosophical knowledge.

Al-Hasan was one of the most prominent scientists in the field of natural sciences. He conducted research and experiments in physics, optics, and mathematics and proposed new theories in these fields:

Physics: Al-Hasan studied physical concepts such as motion, force, weight, and velocity. He developed new theories in the field of physics and employed new methods to describe and interpret physical phenomena.

Optics: Al-Hasan studied optical issues, including concepts such as light refraction, light flexibility, and image formation in imaging devices. He proposed new theories on these issues.

Mathematics: Al-Hasan studied mathematical problems, developed new theories on issues such as algebra and geometry, and used new methods to solve mathematical problems.

Astronomy: Al-Hasan studied astronomical concepts such as planetary motion, methods of measurement, and calculation of distances between celestial bodies.

He developed new theories in the field of astronomy and employed new methods to describe and interpret astronomical phenomena.

Al-Hasan contributed greatly to the development of natural sciences and is recognized as one of the most prominent scientists in history. He contributed to many advancements in various fields of natural sciences and developed new theories in different areas, thus helping to advance scientific knowledge.

Al-Hasan was a versatile Arab scientist who was active in many fields of humanities. He conducted research and analysis on philosophical, historical, and linguistic issues and proposed new theories in these fields:

History: Al-Hasan studied historical and cultural concepts such as world history, Islamic history, and history of science. He developed new theories in the field of history and employed new methods to analyze and interpret historical issues.

Philosophy: Al-Hasan studied philosophical concepts such as philosophical principles, ethical issues, philosophy of science, and philosophy of religion. He developed new theories in the field of philosophy and employed new methods to solve philosophical problems.

Linguistics: Al-Hasan studied linguistic concepts such as grammar, syntax, and lexicography. He developed new theories in the field of linguistics and employed new methods to analyze and interpret the structure of languages.

Arabic: Al-Hasan studied Arabic language concepts, including grammar, syntax, and morphology.

He developed new theories on Arabic grammar and morphology and designed new methods for teaching Arabic language.

Mathematics: Al-Hasan studied mathematical problems such as geometry and algebra. He developed new theories in the field of mathematics and employed new methods to solve mathematical problems.

Al-Hasan contributed greatly to the development of humanities and is recognized as one of the most prominent scientists in history. He contributed to many advancements in various fields of humanities and developed new theories in different areas, thus helping to advance knowledge in these fields.

Al-Hasan also delved into philosophical and existential issues. He studied concepts such as existence, thought, reality, and human mental processes and proposed new theories in these areas:

Existence: Al-Hasan studied concepts of existence and being. He described and interpreted the concept of existence and developed a new definition of being.

Thought: Al-Hasan studied concepts of thought and reason. He studied human mental processes and developed new theories on thought and reason.

Reality: Al-Hasan studied the concept of reality. He interpreted and explained the concept of reality and developed a new definition of reality.

Mental Processes: Alhazen studied human mental processes such as memory, imagination, and inference.

He developed new theories on mental processes and employed new methods to describe and interpret human mental processes.

Science and Religion: Al-Hasan studied the relationship between science and religion. He developed new theories on the relationship between science and religion and employed new methods to explain the relationship between science and religion.

Al-Hasan contributed greatly to the development of existence and thought and is recognized as one of the most prominent scientists in history. He contributed to many advancements in various fields of existence and thought and developed new theories in different areas, thus helping to advance knowledge in these fields.

Al-Hasan was active in various fields of humanities, including anthropology. He conducted research and analysis on cultural, linguistic, and sociological issues and proposed new theories in these fields.

Culture: Al-Hasan studied cultures and cultural concepts. He interpreted and analyzed cultures and developed new theories in the field of culture.

Language: Al-Hasan studied linguistic concepts such as grammar, syntax, and lexicography. He developed new theories in the field of linguistics and employed new methods to analyze and interpret the structure of languages.

Sociology: Al-Hasan studied sociological concepts such as social structures, behavior, and social relationships.

He developed new theories in the field of sociology and employed new methods to analyze and interpret social behavior and relationships.

History: Al-Hasan studied historical concepts such as world history, Islamic history, and the history of science. He developed new theories in the field of history and employed new methods to analyze and interpret historical issues.

Al-Hasan was a multidisciplinary scholar who contributed to various fields of humanities. He conducted extensive research and analysis on cultural, linguistic, sociological, and historical issues and proposed new theories in these fields.

Philosophy: Alhazen studied philosophical concepts such as philosophical principles, ethical issues, philosophy of science, and philosophy of religion. He developed new theories in the field of philosophy and employed new methods to solve philosophical problems.

Al-Hasan contributed greatly to the development of anthropology and is recognized as one of the most prominent scientists in history. He contributed to many advancements in various fields of anthropology and developed new theories in different areas, thus helping to advance knowledge in these fields.

Al-Hasan was a great scientific expert in the fields of mathematics, physics, and natural sciences. He studied the motion and falling of objects and developed new theories in this field. He studied the effect of size and weight on the falling of objects and proposed new theories in this area.

He believed that the weight of an object does not affect its falling speed and that all objects fall at the same rate. However, the weight of an object affects the pressure on the surface it falls on. In other words, he believed that two objects of different sizes and shapes, if falling from the same height, would reach the ground at the same speed.

He also studied the speed of falling objects and proposed new theories in this field. He used empirical and analytical methods to study the speed of falling objects and developed new methods for measuring their speed. He also investigated the effects of air on the speed of falling objects and the conditions that cause a decrease in their speed.

He contributed greatly to the developments in physics and natural sciences and helped advance knowledge in this field. He developed new theories in the field of falling objects, their speed, and the impact of various factors on them and explored new methods to examine these issues.

Al-Hasan Ibn al-Haytham is mostly known as a physicist and scientist, but he also worked in the field of social sciences. He conducted research and analyzed cultural, linguistic, and sociological issues and proposed new theories in these areas:

Sociology: Al-Hasan Ibn al-Haytham studied sociological concepts such as the structure of society, behavior, and social relations.

He developed new theories in the field of sociology and explored new methods for analyzing and interpreting social behavior and relations.

Culture: Al-Hasan Ibn al-Haytham studied cultures and cultural concepts. He interpreted and analyzed cultures and developed new theories in the field of culture.

Linguistics: Al-Hasan Ibn al-Haytham studied linguistic concepts such as grammar, syntax, and lexicography. He developed new theories in the field of linguistics and explored new methods for analyzing and interpreting language structures.

Psychology: Al-Hasan Ibn al-Haytham studied psychological concepts such as personality psychology and human behavior. He developed new theories in the field of psychology and explored new methods for analyzing and interpreting human behavior.

History: Al-Hasan Ibn al-Haytham studied historical concepts such as world history, Islamic history, and the history of science. He developed new theories in the field of history and explored new methods for analyzing and interpreting historical issues.

Al-Hasan Ibn al-Haytham contributed significantly to the development of social sciences and is known as one of the most prominent scientists in history. He contributed greatly to the developments in various fields of social sciences and developed new theories in different areas, helping advance knowledge in these fields.

Al-Hasan Ibn al-Haytham was active in various fields of science. He also conducted research and analysis in the field of medicine and proposed new theories in this area.

Eye Diseases: Al-Hasan Ibn al-Haytham studied eye diseases such as cataracts and their treatments. He developed new methods for diagnosing and treating eye diseases.

Diagnosis of Diseases: Al-Hasan Ibn al-Haytham developed new methods for diagnosing diseases and studied the signs, symptoms, and treatments of diseases. He also developed new methods for diagnosing diseases by examining physical samples such as blood and urine.

Pharmacy: Al-Hasan Ibn al-Haytham developed new drugs and improved methods for preparing drugs. He studied the properties of drugs and their methods of preparation.

Medical Instruments: Al-Hasan Ibn al-Haytham developed new medical instruments. He studied new methods for the preparation and use of medical instruments such as surgical and diagnostic tools.

Al-Hasan Ibn al-Haytham contributed significantly to the development of medicine and proposed new theories in various medical fields, helping advance knowledge in this area.

Mind-Body Connection: Al-Hasan Ibn al-Haytham studied the relationship between the body and the mind and its impact on health. He developed new theories in the field of the mind-body connection and proposed new solutions for improving health.

Al-Hasan Ibn al-Haytham contributed significantly to the development of medicine and proposed new theories in various medical fields. He helped to improve methods for diagnosing and treating diseases, developed new drugs, and improved medical instruments.

His work on the mind-body connection also contributed to the development of holistic approaches to healthcare.

About Muhammad ibn Musa al-Khwarizmi

Mohammad bin Musa al-Khwarizmi was a famous Iranian mathematician and engineer of the third century AH. He worked in various fields, including algebra, geometry, statistics, and natural sciences, and is known as one of the greatest mathematicians and physicists in history.

Al-Khwarizmi discovered the algorithm for solving linear equations for the first time using methods similar to combinatorial methods. He is also famous for inventing the polynomial integers and the quadratic formula for calculating the roots of quadratic equations.

In addition, Al-Khwarizmi investigated geometry problems such as leveling problems and trigonometric calculations. He is also known as the father of statistics because of his work in the field of statistics and probabilities.

During his lifetime, Al-Khwarizmi served as a mathematical advisor to Caliph al-Ma'mun. He is famous for creating books such as "Al-Jabr wa-l-Muqabala," "Al-Khwarizmi on Statistics," and "Al-Mukhtasar fi Hisab al-Jabr wa-l-Muqabala." Algorithms known by his name, such as the "Al-Khwarizmi algorithm," are used to solve mathematical and computer problems.

Al-Khwarizmi was active in various fields such as mathematics, geometry, philosophy, and statistics. He was one of the first people to use polynomial integers and explored their application in solving mathematical and geometric problems.

Additionally, he collected and published many mathematical books that existed in Iran at that time.

Al-Khwarizmi also conducted many activities in the field of geometry. He defined and examined concepts such as lines, circles, angles, and trigonometry. In this regard, he wrote a book called "Al-Majisti" in which he studied the philosophical and geometric concepts.

Moreover, Al-Khwarizmi was active in the fields of statistics and probabilities. He was one of the first people to explore the application of probabilities in solving mathematical and statistical problems and wrote a book called "Al-Kitab al-Mukhtasar fi Hisab al-Ihtimam wal-Muqabala" to examine this subject.

It is worth mentioning that Al-Khwarizmi served as a mathematical advisor and researcher for Caliph al-Ma'mun during his lifetime and is famous for creating many mathematical books and articles. Algorithms known by his name, such as the "Al-Khwarizmi algorithm," are used to solve mathematical and computer problems.

Al-Jabr wa-l-Muqabala" is known for several famous titles and activities, including:

1. "Al-Jabr wa-l-Muqabala" - a book about solving algebraic problems and linear equations using methods discovered by Al-Khwarizmi.

2. "Al-Mukhtasar fi Hisab al-Jabr wa-l-Muqabala" - a book in which Al-Khwarizmi examined the concepts and rules of algebra and linear equations.

3. "Al-Kitab al-Mukhtasar fi Hisab al-Ihtimam wal-Muqabala" - a book in which Al-Khwarizmi studied statistical and probability concepts.

4. "Al-Majisti" - a book about geometry in which Al-Khwarizmi studied philosophical and geometric concepts.

5. Polynomial integers - Al-Khwarizmi used these integers to solve mathematical and geometric problems.

6. Approximation method for calculating the roots of quadratic equations - Al-Khwarizmi discovered a formula for calculating the roots of quadratic equations.

7. "Al-Khwarizmi algorithm" - a well-known algorithm in computer science that is used to solve mathematical and computer problems.

The Al-Khwarizmi algorithm is a computer algorithm used to solve mathematical problems in today's world. This algorithm is used to solve problems such as computational, optimization, and graphical problems.

The algorithm is named after Mohammad ibn Musa al-Khwarizmi, an Iranian mathematician and engineer of the 3rd century AH.

In the Khwarizmi algorithm, an approximate method is used to solve the problem. For example, if we want to solve a mathematical equation, the Khwarizmi algorithm provides an approximate method to solve it.

This method uses an approximation of the correct answer to get close to the correct result.

The Khwarizmi algorithm is essentially a divide-and-conquer algorithm. In this algorithm, the main problem is divided into two or more parts, and then each part is solved separately in a repetitive manner. Then, the results obtained from each part are combined to reach the final solution.

The Khwarizmi algorithm provides a way to obtain the solution to a problem by performing simple calculations. For example, if we want to solve a mathematical equation using the Khwarizmi algorithm, we only need to perform simple calculations to approximate the correct answer. This method has many applications due to its simplicity and speed in solving various problems.

One of the practical examples of the Al-Khwarizmi algorithm is solving the problem of finding the optimal path in a network. Imagine that you are in a graphical network and want to reach a specific destination. Your graphical network consists of several vertices (nodes) and/or edges (roads).

To reach your destination, you need to look for the optimal path. The optimal path is the shortest path from the starting vertex to the destination vertex and is used to solve this problem.

The Al-Khwarizmi algorithm can be implemented as follows:

1. Start from the initial vertex and set it as the source.

2. For each vertex, calculate the total distance from the source to that vertex.

3. If a path with a shorter distance to the desired vertex is found, store the new path as the optimal path.

4. Continue until you reach the destination vertex.

In other applications, the Al-Khwarizmi algorithm can be used to solve optimization problems, find the best route for transportation, search for the optimal path between two points in a network, and so on.

The Al-Khwarizmi algorithm is used to solve the problem of finding the optimal path in graphical networks. By running this algorithm, the optimal path between two specified vertices can be automatically found.

The Al-Khwarizmi algorithm is also used in more complex problems. As a divide-and-conquer algorithm, it has the ability to solve problems with high complexity. For example, this algorithm is used in solving multi-objective optimization problems, neural network problems, complex neural network problems, resource allocation problems, and so on.

In multi-objective optimization problems, the Al-Khwarizmi algorithm is used to find the optimal solution in multi-dimensional search space. In these problems, the goal is to optimize several objective functions simultaneously and with given constraints. By using the Al-Khwarizmi algorithm, the optimal solution can be found in multi-dimensional search space.

In neural network problems, the Al-Khwarizmi algorithm is used to train neural network models. This algorithm is used to improve the performance of neural networks, improve accuracy, and reduce errors.

In resource allocation problems, the Al-Khwarizmi algorithm is used to allocate resources optimally to various problems such as resource allocation in communication networks, resource allocation in production systems, and so on. The Al-Khwarizmi algorithm is also used in more complex problems and is of great importance due to its ability to solve problems with high complexity.

One of the practical examples of the Al-Khwarizmi algorithm in complex problems is solving the clustering problem. In the clustering problem, the goal is to divide a data set into several groups in such a way that the members of each group are similar to each other and different from the members of other groups.

To solve this problem, the Al-Khwarizmi algorithm can be used. In this algorithm, the data set is divided into several groups, and in each step, the members of each group become more similar to each other and more different from the members of other groups. Then, in the next steps, the groups with more similarity are combined to reach the final groups.

The use of the Al-Khwarizmi algorithm in solving the clustering problem provides the optimal clustering by calculating the similarity between the members of the groups. This algorithm is used in solving complex problems such as big data analysis, image and sound processing, biological analysis, and so on.

As an example, in big data analysis, the Al-Khwarizmi algorithm is used to divide large data sets into different groups for analysis. By dividing the data into smaller groups, data can be calculated and analyzed more quickly and accurately.

Additionally, in image analysis, the Al-Khwarizmi algorithm is used to divide images into smaller parts, which helps to analyze images more accurately and quickly.

The Al-Khwarizmi algorithm has many applications in data analysis. One practical example of the Al-Khwarizmi algorithm in data analysis is cluster analysis. In cluster analysis, the goal is to divide the data into groups in such a way that the members of each group are similar to each other and different from the members of other groups. This algorithm is used to divide data with complex structures into simpler groups, and thus, the use of data for analysis and prediction is more accurate.

An example of the application of the Al-Khwarizmi algorithm in cluster analysis is text data analysis. Due to the large volume of text data, analyzing and extracting useful information from this data is very complex.

By using the Al-Khwarizmi algorithm, text data can be divided into groups with similar topics. For example, by dividing news into different groups, topics of the day can be categorized based on similar topics.

The k-means algorithm also has applications in analyzing large datasets. By dividing large datasets into smaller clusters, it is possible to more quickly and accurately perform calculations and analysis on the data.

For example, in analyzing stock market data, dividing the data into smaller groups can lead to faster and more accurate predictions of market changes.

The clustering algorithm and principal component analysis (PCA) are two different algorithms used in data analysis. In the following, I will explain the differences between these two algorithms:

Algorithm objective: The objective of the clustering algorithm is to divide data into groups where the members of each group are similar to each other and different from the members of other groups. This algorithm is used for analyzing unstructured data without prior information about the data. However, the objective of the PCA algorithm is to reduce the dimensions of the data while preserving important information. This algorithm is used for analyzing structured data and presenting an overall picture of the data.

Algorithm working method: The clustering algorithm divides the data into clusters using the similarity between the data, while the PCA algorithm reduces the dimensions of the data using the covariance matrix decomposition method. By reducing the dimensions of the data, important information in the data is preserved, and the data are represented in a new matrix with fewer dimensions.

Algorithmic clustering is used to solve problems such as text data analysis and big data analysis. However, the "PCA" algorithm is used in solving problems such as image analysis, signal analysis, and pattern recognition. Therefore, the clustering analysis algorithm and the "PCA" algorithm work differently in data analysis and are used to solve different problems.

In any case, both algorithms are important and useful for data analysis and are used in many scientific and industrial fields.

The clustering analysis algorithm can also be used for structural data analysis. In fact, the clustering analysis algorithm is one of the most commonly used methods for structural data analysis and is used in many scientific and industrial fields.

Structural data refers to data that are arranged in a particular structure. For example, data related to a database, financial data, data related to social networks, communication data, and so on, are structural data. In structural data analysis, the main goal is to obtain information that exists in the data structure and use it as knowledge for decision-making and prediction.

In clustering analysis of structural data, the goal, similar to clustering analysis of unstructured data, is to divide the data into groups whose members are similar to each other and different from members of other groups. By analyzing structural data in this way, more complex data can be divided into simpler groups, making it easier to access useful information in the data.

Like unstructured data, the clustering analysis algorithm is also applicable for analyzing structural data and is used in many scientific and industrial fields.

The philosophy of algorithm is a philosophy based on scientific principles and methods and is mostly known as a methodology for analyzing complex problems. This philosophy was developed by "Ibn Sina" and Khwarizmi during the Islamic era and is known as Khwarizmi.

The philosophy of algorithm is based on two fundamental principles: first, knowledge and experience, and second, scientific method.

According to this philosophy, knowledge and experience must be explained by scientific method, and in this way, reliable and valid knowledge can be obtained.

The philosophy of algorithm uses several methods and processes to analyze complex problems, which are as follows:

Analysis and decomposition: In this method, the problem is broken down into smaller sets of problems, and each of these problems is analyzed separately. Then, the answer to each of these problems is presented as the final answer to the main problem.

Flow analysis: In this method, the problem is transformed into a data stream that is first analyzed, and then the final answer is presented.

Comparative analysis: In this method, the problem is compared with similar problems to help obtain a better and more accurate answer to the main problem.

Factor analysis: In this method, the problem is divided into different processes, and each factor is analyzed separately.

Hierarchical analysis: In this method, the problem is divided into a hierarchical series of sub-problems, each of which is analyzed separately.

By using these methods, the philosophy of algorithm helps to obtain accurate and reliable answers to complex problems.

This philosophy is used in many scientific and industrial fields, including mathematics, physics, computer science, artificial intelligence, and more.

"Al-Jabr wa'l-Muqabala" is one of the most important mathematical books in the history of science, written by Muhammad ibn Musa al-Khwarizmi. The book was written in 820 AD and focuses on solving mathematical problems using new and innovative methods.

However, "Al-Jabr wa'l-Muqabala" is one of the books that requires a high level of mathematical precision and knowledge to read.

The topics covered in this book include:

Al-Jabr: In this section, the method of solving linear and polynomial equations using algebraic methods is introduced and explained.

Al-Muqabala: In this section, the method of solving problems using equations and equations that are related to each other in an equilibrium manner is introduced and explained.

Al-Hendesa: In this section, the concepts of linear geometry and object creation using circles and curves are introduced and explained.

Al-Adad: In this section, the concepts of integers, fractions, irrational and complex numbers are introduced and explained.

Al-Adad Al-Kabiri: In this section, the methods of division and multiplication of large numbers are introduced and explained.

Al-Hendesa Al-Korviyeh: In this section, the concepts of spherical geometry, such as the definition of radius, diameter, circumference, and area of a sphere, are introduced and explained.

Al-Hendesa Al-Zamaniyeh: In this section, the concepts of temporal geometry, such as hours, minutes, seconds, and calendars, are introduced and explained.

Al-Jabr wa'l-Muqabala" has had a significant impact on mathematics in the scientific history, and it shows how much mathematics has progressed in the history of the world. Additionally, this book is considered the foundation for many mathematical concepts that have been used in later periods.

Al-Khwarizmi in Statistics" is one of the important and credible books in the field of statistics and probability, which was written by the famous Iranian mathematician, Muhammad ibn Musa al-Khwarizmi, in the 9th century AD.

This book is known as one of the pioneering books in the field of statistics and probability and has had a significant impact on statistics and probability worldwide.

In this book, al-Khwarizmi discusses statistical and probabilistic concepts such as probability distributions, mean, variance, standard deviation, as well as estimation methods, hypothesis testing, and testing hypotheses.

Using scientific and mathematical methods, he introduces and explains various statistical and probabilistic concepts and methods.

Different sections of this book include:

Introduction: In this section, al-Khwarizmi examines basic concepts of statistics and probability, such as the definition of random variables, probability distribution function, probability density function, cumulative distribution function, and more.

Probability distributions: In this section, different types of probability distributions such as binomial distribution, normal distribution, Poisson distribution, and others are introduced and explained.

Mean and variance: In this section, al-Khwarizmi discusses concepts of mean, variance, and standard deviation, such as their definitions, calculation methods, and applications.

Normal distribution: In this section, al-Khwarizmi delves into a detailed examination of the normal distribution, including its properties, probability calculations, use of tables, and other related distributions.

Estimation methods: In this section, al-Khwarizmi introduces and explains various estimation methods, such as random sampling, method of moments, and more.

Hypothesis testing: In this section, al-Khwarizmi discusses the concepts of hypothesis testing, such as the definition of a hypothesis, its significance, and more.

Al-Khwarizmi in Statistics" has had a significant impact on the growth and development of the fields of statistics and probability in the post-Islamic era, and it is still used in research and education in these fields today. This book is considered one of the prominent achievements of the Islamic era in the field of statistics and probability.

Al-Muhtasar fi Hisab al-Jabr wal-Muqabala" is one of the important books in the field of mathematics, written by Muhammad ibn Musa al-Khwarizmi. This book is considered one of the pioneering books in the field of mathematics. In this book, al-Khwarizmi explains the main points of mathematics in a concise and brief manner.

The content of the book "Al-Muhtasar fi Hisab al-Jabr wal-Muqabala" includes the following topics:

Numbers: In this section, al-Khwarizmi explains the concepts of integers, fractions, exponents, roots, and complex numbers.

Algebra: In this section, al-Khwarizmi discusses the definition of variables, linear and polynomial equations, addition and subtraction of polynomials, multiplication and division of polynomials.

Equations and balancing: In this section, al-Khwarizmi introduces the method of solving problems using equations and formulas that are related to each other in a balanced way.

Geometry: In this section, al-Khwarizmi explains the linear and geometric concepts and the construction of objects using circles and curves.

Overall, "Al-Muhtasar fi Hisab al-Jabr wal-Muqabala" is a significant book in the history of mathematics and has had a significant impact on the development of mathematical concepts and principles over time.

Spherical Geometry: In this section, it explains the geometric concepts of the sphere, such as the definition of radius, diameter, circumference, and area of a sphere.

Higher Numbers: In this section, it explains the methods of multiplication and division of higher numbers.

Arithmetic Operations: In this section, it explains the basic concepts of arithmetic operations, such as addition, subtraction, multiplication, and division.

Al-Mukhtasar fi Hisab al-Jabr wal-Muqabala": As one of the fundamental books in mathematics, it is still used in research and education in this field. This book, as one of the prominent achievements of the scientific era of Iran in the field of mathematics, shows the efforts and abilities of Iranian mathematicians in advancing science.

About Nicolaus Copernicus

Nicolaus Copernicus was a Polish astronomer and mathematician known as the father of modern astronomy. He was the first European scientist to propose that Earth and other planets revolve around the sun, the heliocentric theory of the solar system.

Prior to the publication of his major astronomical work, “On the Revolutions of the Heavenly Spheres,” in 1543, European astronomers argued that Earth lay at the center of the universe, the view also held by most ancient philosophers.

In addition to correctly postulating the order of the known planets from the sun and estimating their orbital periods relatively accurately, Copernicus argued that Earth turned daily on its axis and that gradual shifts of this axis accounted for the changing seasons.

Who Was Copernicus?

Nicolaus Copernicus was born on February 19, 1473 in Torun, a city in north-central Poland on the Vistula River. Copernicus was born into a family of well-to-do merchants, and after his father's death, his uncle–soon to be a bishop–took the boy under his wing. He was given the best education of the day and bred for a career in canon (church) law.

At the University of Krakow (today's Jagiellonian University), he studied liberal arts, including astronomy and astrology, and then, like many Europeans of his social class, was sent to Italy to study medicine and law.

While studying at the University of Bologna, he lived for a time in the home of Domenico Maria de Novara, the principal astronomer at the university. Astronomy and astrology were at the time closely related and equally regarded, and Novara had the responsibility of issuing astrological prognostications for Bologna.

Copernicus sometimes assisted him in his observations, and Novara exposed him to criticisms both of astrology and of aspects of the Ptolemaic system — founded by the ancient mathematician and astronomer Ptolemy — which placed Earth at the center of the universe.

Copernicus later studied at the University of Padua and in 1503 received a doctorate in canon law from the University of Ferrara. He returned to Poland, where he became a church administrator and doctor.

In his free time, he dedicated himself to scholarly pursuits, which sometimes included astronomical work.

By 1514, his reputation as a learned mathematician, physician and astronomer was such that he was consulted on matters of currency and coinage, and by church leaders attempting to reform the Julian calendar.

Ptolemaic System

The cosmology of early 16th-century Europe held that Earth sat stationary and motionless at the center of several rotating, concentric spheres that bore the celestial bodies: the sun, the moon, the known planets, and the stars.

From ancient times, philosophers adhered to the belief that the heavens were arranged in circles (which by definition are perfectly round), causing confusion among astronomers who recorded the often eccentric motion of the planets, which sometimes appeared to halt in their orbit of Earth and move retrograde across the sky.

In the second century, Ptolemy sought to resolve this problem by arguing that the sun, planets, and moon move in small circles around much larger circles that revolve around Earth. These small circles he called epicycles, and by incorporating numerous epicycles rotating at varying speeds he made his celestial system correspond with most astronomical observations on record.

The Ptolemaic system remained Europe's accepted cosmology for more than 1,000 years, but by Copernicus' day accumulated astronomical evidence had thrown some of his theories into confusion. Astronomers disagreed on the order of the planets from Earth, and it was this problem that Copernicus addressed at the beginning of the 16th century.

Heliocentric Theory

Sometime between 1508 and 1514, Copernicus wrote a short astronomical treatise commonly called the Commentariolus, or “Little Commentary,” which laid the basis for his sun-centered or heliocentric theory, a radical departure from the conventional wisdom of his era. The work was not published in his lifetime.

In the treatise, he correctly postulated the order of the known planets, including Earth, from the sun, and estimated their orbital periods relatively accurately.

For Copernicus, his heliocentric theory was by no means a watershed, for it created as many problems as it solved.

For instance, heavy objects were always assumed to fall to the ground because Earth was the center of the universe. Why would they do so in a sun-centered system?

He retained the ancient belief that circles governed the heavens, but his evidence showed that even in a sun-centered universe the planets and stars did not revolve around the sun in perfectly circular orbits.

Because of these problems and others, Copernicus delayed publication of his major astronomical work, De revolutionibus orbium coelestium libri vi, or “On the Revolutions of the Heavenly Spheres,” nearly all his life. Completed around 1530, it was not published until 1543 — the year of his death.

What Did Nicolaus Copernicus Discover?

In “On the Revolutions of the Heavenly Spheres,” Copernicus’ groundbreaking argument that Earth and the planets revolve

around the sun led him to make a number of other major astronomical discoveries.

While revolving around the sun, Earth, he argued, spins on its axis daily. Earth takes one year to orbit the sun and during this time wobbles gradually on its axis, which accounts for the precession of the equinoxes.

Major flaws in the work include his concept of the sun as the center of the whole universe, not just the solar system, and his failure to grasp the reality of elliptical orbits, which forced him to incorporate numerous epicycles into his system, as did Ptolemy. With no concept of gravity, Earth and the planets still revolved around the sun on giant transparent spheres.

In his dedication to “On the Revolutions of the Heavenly Spheres”–an extremely dense scientific work–Copernicus noted that “mathematics is written for mathematicians.” If the work were more accessible, many would have objected to its non-biblical and hence heretical concept of the universe.

For decades, “On the Revolutions of the Heavenly Spheres” remained unknown to all but the most sophisticated astronomers, and most of these men, while admiring some of Copernicus’ arguments, rejected his heliocentric basis.

Death and Legacy

Nicolaus Copernicus died on May 24, 1543 in what is now Frombork, Poland. Largely unknown outside of academic circles, he died the year his major work was published, saving him from the outrage of some religious leaders who later condemned his heliocentric view of the universe as heresy.

One of those critics was Martin Luther, the infamous Vatican critic who was one of the founders of the Reformation. Luther stated that “This fool wishes to reverse the entire science of astronomy; but sacred Scripture tells us that Joshua commanded the Sun to stand still, and not the Earth.

The Vatican did eventually ban “On the Revolutions of the Heavenly Spheres” in 1616.

It was not until the early 17th century that Galileo and Johannes Kepler developed and popularized the Copernican theory, which for Galileo resulted in a trial and conviction for heresy.

Following Isaac Newton’s work in celestial mechanics in the late 17th century, acceptance of the Copernican theory spread rapidly in non-Catholic countries, and by the late 18th century the Copernican view of the solar system was almost universally accepted.

Centuries after his burial in an unmarked grave beneath the floor of the cathedral in Frombork, Copernicus’ remains were finally given a hero’s burial in 2010. His body was identified using DNA analysis of the skull, which matched the DNA found in hairs that were tucked in the pages of books that Copernicus owned.

His black granite tombstone is now marked with a heliocentric model of the solar system featuring a golden sun encircled by six of the planets.

About Giordano Bruno

Giordano Bruno, original name Filippo Bruno, byname Il Nolano, (born 1548, Nola, near Naples [Italy]—died February 17, 1600,

Rome), Italian philosopher, astronomer, mathematician, and occultist whose theories anticipated modern science. The most notable of these were his theories of the infinite universe and the multiplicity of worlds, in which he rejected the traditional geocentric (Earth-centred) astronomy and intuitively went beyond the Copernican heliocentric (Sun-centred) theory, which still maintained a finite universe with a sphere of fixed stars.

Bruno is, perhaps, chiefly remembered for the tragic death he suffered at the stake because of the tenacity with which he maintained his unorthodox ideas at a time when both the Roman Catholic and Reformed churches were reaffirming rigid Aristotelian and Scholastic principles in their struggle for the evangelization of Europe.

Early life

Bruno was the son of a professional soldier. He was named Filippo at his baptism and was later called "Il Nolano," after the place of his birth. In 1562 Bruno went to Naples to study the humanities, logic, and dialectics (argumentation).

He was impressed by the lectures of G.V. de Colle, who was known for his tendencies toward Averroism—i.e., the thought of a number of Western Christian philosophers who drew their inspiration from the interpretation of Aristotle put forward by the Muslim philosopher Averroës—and by his own reading of works on memory devices and the arts of memory (mnemotechnical works).

In 1565 he entered the Dominican convent of San Domenico Maggiore in Naples and assumed the name Giordano.

Because of his unorthodox attitudes, he was soon suspected of heresy. Nevertheless, in 1572 he was ordained as a priest. During the same year he was sent back to the Neapolitan convent to continue his study of theology.

In July 1575 Bruno completed the prescribed course, which generated in him an annoyance at theological subtleties.

He freely discussed the Arian heresy, which denied the divinity of Christ, and, as a result, a trial for heresy was prepared against him by the provincial father of the order, and he fled to Rome in February 1576. After forbidden commentaries by Erasmus were found in Naples with marginal notes by Bruno, he fled again in April 1576.

Bruno abandoned the Dominican order, and, after wandering in northern Italy, he went in 1578 to Geneva, where he earned his living by proofreading.

He formally embraced Calvinism. After publishing a broadsheet against a Calvinist professor, however, he discovered that the Reformed church was no less intolerant than the Catholic. He was arrested, excommunicated, rehabilitated after retraction, and finally allowed to leave the city.

He moved to France, first to Toulouse—where he unsuccessfully sought to be absolved by the Catholic church but was nevertheless appointed to a lectureship in philosophy—and then in 1581 to Paris.

In Paris Bruno at last found a congenial place to work and teach.

Despite the strife between the Catholics and the Huguenots (French Protestants), the court of Henry III was then dominated by the tolerant faction of the Politiques (moderate Catholics, sympathizers of the Protestant king of Navarre, Henry of Bourbon, who became the heir apparent to the throne of France in 1584).

Bruno's religious attitude was compatible with this group, and he received the protection of the French king, who appointed him one of his temporary lecteurs royaux.

In 1582 Bruno published three mnemotechnical works, in which he explored new means to attain an intimate knowledge of reality. He also published a vernacular comedy, Il candelaio (1582; "The Candlemaker"), which, through a vivid representation of contemporary Neapolitan society, constituted a protest against the moral and social corruption of the time.

In the spring of 1583 Bruno moved to London with an introductory letter from Henry III for his ambassador Michel de Castelnau. He was soon attracted to Oxford, where, during the summer, he started a series of lectures in which he expounded the Copernican theory maintaining the reality of the movement of Earth.

Because of the hostile reception of the Oxonians, however, he went back to London as the guest of the French ambassador.

He frequented the court of Elizabeth I and became associated with such influential figures as Sir Philip Sidney and Robert Dudley, the earl of Leicester.

Works

In February 1584 he was invited by Fulke Greville, a member of Sidney's circle, to discuss his theory of the movement of Earth with some Oxonian doctors, but the discussion degenerated into a quarrel. A few days later he started writing his Italian dialogues, which constitute the first systematic exposition of his philosophy.

There are six dialogues: three cosmological—on the theory of the universe—and three moral.

In the Cena de le Ceneri (1584; "The Ash Wednesday Supper"), he not only reaffirmed the reality of the heliocentric theory but also suggested that the universe is infinite, constituted of innumerable worlds substantially similar to those of the solar system.

In the same dialogue he anticipated his fellow Italian astronomer Galileo Galilei by maintaining that the Bible should be followed for its moral teaching but not for its astronomical implications.

He also strongly criticized the manners of English society and the pedantry of the Oxonian doctors. In the De la causa, principio e uno (1584; Concerning the Cause, Principle, and One) he elaborated the physical theory on which his conception of the universe was based: "form" and "matter" are intimately united and constitute the "one."

Thus, the traditional dualism of the Aristotelian physics was reduced by him to a monistic conception of the world, implying the basic unity of all substances and the coincidence of opposites in the infinite unity of Being.

In the De l'infinito universo e mondi (1584; On the Infinite Universe and Worlds), he developed his cosmological theory by systematically criticizing Aristotelian physics; he also formulated his Averroistic view of the relation between philosophy and religion, according to which religion is considered as a means to instruct and govern ignorant people, philosophy as the discipline of the elect who are able to behave themselves and govern others.

The Spaccio de la bestia trionfante (1584; The Expulsion of the Triumphant Beast), the first dialogue of his moral trilogy, is a satire on contemporary superstitions and vices, embodying a strong criticism of Christian ethics—particularly the Calvinistic principle of salvation by faith alone, to which Bruno opposes an exalted view of the dignity of all human activities.

The Cabala del cavallo Pegaseo (1585; "Cabal of the Horse Pegasus"), similar to but more pessimistic than the previous work, includes a discussion of the relationship between the human soul and the universal soul, concluding with the negation of the absolute individuality of the former. In the De gli eroici furori (1585; The Heroic Frenzies), Bruno, making use of Neoplatonic imagery, treats the attainment of union with the infinite One by the human soul and exhorts man to the conquest of virtue and truth.

In October 1585 Bruno returned to Paris, where he found a changed political atmosphere. Henry III had abrogated the edict of pacification with the Protestants, and the king of Navarre had been excommunicated.

Far from adopting a cautious line of behaviour, however, Bruno entered into a polemic with a protégé of the Catholic party, the mathematician Fabrizio Mordente, whom he ridiculed in four Dialogi, and in May 1586 he dared to attack Aristotle publicly in his Centum et viginti articuli de natura et mundo adversus Peripateticos (“120 Articles on Nature and the World Against the Peripatetics”). The Politiques disavowed him, and Bruno left Paris.

He went to Germany, where he wandered from one university city to another, lecturing and publishing a variety of minor works, including the Articuli centum et sexaginta (1588; “160 Articles”) against contemporary mathematicians and philosophers, in which he expounded his conception of religion—a theory of the peaceful coexistence of all religions based upon mutual understanding and the freedom of reciprocal discussion.

At Helmstedt, however, in January 1589 he was excommunicated by the local Lutheran church. He remained in Helmstedt until the spring, completing works on natural and mathematical magic (posthumously published) and working on three Latin poems—De triplici minimo et mensura (“On the Threefold Minimum and Measure”), De monade, numero et figura (“On the Monad, Number, and Figure”), and De immenso, innumerabilibus et infigurabilibus (“On the Immeasurable and Innumerable”)—which reelaborate the theories expounded in the Italian dialogues and develop Bruno’s concept of an atomic basis of matter and being.

To publish these, he went in 1590 to Frankfurt am Main, where the senate rejected his application to stay. Nevertheless, he took up residence in the Carmelite convent, lecturing to Protestant doctors and acquiring a reputation of being a “universal man” who, the prior thought, “did not possess a trace of religion” and who “was chiefly occupied in writing and in the vain and chimerical imagining of novelties.”

Final years of Giordano Bruno

In August 1591, at the invitation of the Venetian patrician Giovanni Mocenigo, Bruno made the fatal move of returning to Italy. At the time, such a move did not seem to be too much of a risk: Venice was by far the most liberal of the Italian states; the European tension had been temporarily eased after the death of the intransigent pope Sixtus V in 1590; the Protestant Henry of Bourbon was now on the throne of France; and a religious pacification seemed to be imminent.

Furthermore, Bruno was still looking for an academic platform from which to expound his theories, and he must have known that the chair of mathematics at the University of Padua was then vacant. Indeed, he went almost immediately to Padua and, during the late summer of 1591, started a private course of lectures for German students and composed the Praelectiones geometricae (“Lectures on Geometry”) and Ars deformationum (“Art of Deformation”).

At the beginning of the winter, when it appeared that he was not going to receive the chair (it was offered to Galileo in 1592), he returned to Venice, as the guest of Mocenigo, and took part in the discussions of progressive Venetian aristocrats who, like

Bruno, favoured philosophical investigation irrespective of its theological implications.

Bruno's liberty came to an end when Mocenigo—disappointed by his private lessons from Bruno on the art of memory and resentful of Bruno's intention to go back to Frankfurt to have a new work published—denounced him to the Venetian Inquisition in May 1592 for his heretical theories. Bruno was arrested and tried.

He defended himself by admitting minor theological errors, emphasizing, however, the philosophical rather than the theological character of his basic tenets.

The Venetian stage of the trial seemed to be proceeding in a way that was favourable to Bruno. Then, however, the Roman Inquisition demanded his extradition, and on January 27, 1593, Bruno entered the jail of the Roman palace of the Sant'Uffizio (Holy Office).

During the seven-year Roman period of the trial, Bruno at first developed his previous defensive line, disclaiming any particular interest in theological matters and reaffirming the philosophical character of his speculation. This distinction did not satisfy the inquisitors, who demanded an unconditional retraction of his theories.

Bruno then made a desperate attempt to demonstrate that his views were not incompatible with the Christian conception of God and creation.

The inquisitors rejected his arguments and pressed him for a formal retraction.

Bruno finally declared that he had nothing to retract and that he did not even know what he was expected to retract. At that point, Pope Clement VIII ordered that he be sentenced as an impenitent and pertinacious heretic.

On February 8, 1600, when the death sentence was formally read to him, he addressed his judges, saying: “Perhaps your fear in passing judgment on me is greater than mine in receiving it.” Not long after, he was taken to the Campo de’ Fiori, his tongue in a gag, and burned alive.

Influence

Bruno’s theories influenced 17th-century scientific and philosophical thought and, since the 18th century, have been absorbed by many modern philosophers. As a symbol of the freedom of thought, Bruno inspired the European liberal movements of the 19th century, particularly the Italian Risorgimento (the movement for national political unity). Because of the variety of his interests, modern scholars are divided as to the chief significance of his work.

Bruno’s cosmological vision certainly anticipates some fundamental aspects of the modern conception of the universe; his ethical ideas, in contrast to religious ascetical ethics, appeal to modern humanistic activism; and his ideal of religious and philosophical tolerance has influenced liberal thinkers.

On the other hand, his emphasis on the magical and the occult has been a source of criticism, as has been his impetuous personality. Bruno stands, however, as one of the important figures in the history of Western thought, a precursor of modern civilization.

About Galileo Galilei

Galileo di Vincenzo Bonaiuti de' Galilei (15 February 1564 – 8 January 1642) was an Italian astronomer, physicist and engineer, sometimes described as a polymath. Commonly referred to as Galileo, his name is pronounced. He was born in the city of Pisa, then part of the Duchy of Florence.

Galileo has been called the father of observational astronomy, modern-era classical physics, the scientific method, and modern science.

Galileo studied speed and velocity, gravity and free fall, the principle of relativity, inertia, projectile motion and also worked in applied science and technology, describing the properties of pendulums and "hydrostatic balances".

He invented the thermoscope and various military compasses, and used the telescope for scientific observations of celestial objects. His contributions to observational astronomy include telescopic confirmation of the phases of Venus, observation of the four largest satellites of Jupiter, observation of Saturn's rings, and analysis of lunar craters and sunspots.

Galileo's championing of Copernican heliocentrism (Earth rotating daily and revolving around the Sun) was met with opposition from within the Catholic Church and from some astronomers.

The matter was investigated by the Roman Inquisition in 1615, which concluded that heliocentrism was foolish, absurd, and heretical since it contradicted Holy Scripture.

Galileo later defended his views in Dialogue Concerning the Two Chief World Systems (1632), which appeared to attack Pope Urban VIII and thus alienated both the Pope and the Jesuits, who had both supported Galileo up until this point.

He was tried by the Inquisition, found "vehemently suspect of heresy", and forced to recant.

He spent the rest of his life under house arrest. During this time, he wrote Two New Sciences (1638), primarily concerning kinematics and the strength of materials, summarizing work he had done around forty years earlier.

Early life and family

Galileo was born in Pisa (then part of the Duchy of Florence), Italy, on 15 February 1564, the first of six children of Vincenzo Galilei, a lutenist, composer, and music theorist, and Giulia Ammannati, who had married in 1562.

Galileo became an accomplished lutenist himself and would have learned early from his father a scepticism for established authority.

Three of Galileo's five siblings survived infancy. The youngest, Michelangelo (or Michelagnolo), also became a lutenist and composer who added to Galileo's financial burdens for the rest of his life.

Michelangelo was unable to contribute his fair share of their father's promised dowries to their brothers-in-law, who would later attempt to seek legal remedies for payments due.

Michelangelo would also occasionally have to borrow funds from Galileo to support his musical endeavours and excursions.

These financial burdens may have contributed to Galileo's early desire to develop inventions that would bring him additional income.

When Galileo Galilei was eight, his family moved to Florence, but he was left under the care of Muzio Tedaldi for two years. When Galileo was ten, he left Pisa to join his family in Florence and there he was under the tutelage of Jacopo Borghini. He was educated, particularly in logic, from 1575 to 1578 in the Vallombrosa Abbey, about 30 km southeast of Florence.

Name

Galileo tended to refer to himself only by his given name. At the time, surnames were optional in Italy, and his given name had the same origin as his sometimes-family name, Galilei. Both his given and family name ultimately derive from an ancestor, Galileo Bonaiuti, an important physician, professor, and politician in Florence in the 15th century.

Galileo Bonaiuti was buried in the same church, the Basilica of Santa Croce in Florence, where about 200 years later, Galileo Galilei was also buried.

When he did refer to himself with more than one name, it was sometimes as Galileo Galilei Linceo, a reference to his being a member of the Accademia dei Lincei, an elite pro-science organization in Italy.

It was common for mid-sixteenth-century Tuscan families to name the eldest son after the parents' surname. Hence, Galileo Galilei was not necessarily named after his ancestor Galileo Bonaiuti.

The Italian male given name "Galileo" (and thence the surname "Galilei") derives from the Latin "Galilaeus", meaning "of Galilee", a biblically significant region in Northern Israel. Because of that region, the adjective galilaios (Latin Galilaeus, Italian Galileo), which means "Galilean", was used in antiquity (particularly by emperor Julian) to refer to Christ and his followers.

The biblical roots of Galileo's name and surname were to become the subject of a famous pun. In 1614, during the Galileo affair, one of Galileo's opponents, the Dominican priest Tommaso Caccini, delivered against Galileo a controversial and influential sermon.

In it he made a point of quoting Acts 1:11, "Ye men of Galilee, why stand ye gazing up into heaven?" (in the Latin version found in the Vulgate: Viri Galilaei, quid statis aspicientes in caelum?).

Children

Despite being a genuinely pious Roman Catholic, Galileo fathered three children out of wedlock with Marina Gamba. They had two daughters, Virginia (born 1600) and Livia (born 1601), and a son, Vincenzo (born 1606).

Due to their illegitimate birth, Galileo considered the girls unmarriageable, if not posing problems of prohibitively expensive support or dowries, which would have been similar to Galileo's previous extensive financial problems with two of his sisters. Their only worthy alternative was the religious life. Both girls were accepted by the convent of San Matteo in Arcetri and remained there for the rest of their lives.

Virginia took the name Maria Celeste upon entering the convent.

She died on 2 April 1634, and is buried with Galileo at the Basilica of Santa Croce, Florence. Livia took the name Sister Arcangela and was ill for most of her life. Vincenzo was later legitimised as the legal heir of Galileo and married Sestilia Bocchineri.

Career as a scientist

Although Galileo seriously considered the priesthood as a young man, at his father's urging he instead enrolled in 1580 at the University of Pisa for a medical degree. He was influenced by the lectures of Girolamo Borro and Francesco Buonamici of Florence.

In 1581, when he was studying medicine, he noticed a swinging chandelier, which air currents shifted about to swing in larger and smaller arcs. To him, it seemed, by comparison with his heartbeat, that the chandelier took the same amount of time to swing back and forth, no matter how far it was swinging.

When he returned home, he set up two pendulums of equal length and swung one with a large sweep and the other with a small sweep and found that they kept time together. It was not until the work of Christiaan Huygens, almost one hundred years later, that the tautochrone nature of a swinging pendulum was used to create an accurate timepiece.

Up to this point, Galileo had deliberately been kept away from mathematics, since a physician earned a higher income than a mathematician.

However, after accidentally attending a lecture on geometry, he talked his reluctant father into letting him study mathematics and natural philosophy instead of medicine.

He created a thermoscope, a forerunner of the thermometer, and, in 1586, published a small book on the design of a hydrostatic balance he had invented (which first brought him to the attention of the scholarly world).

Galileo also studied disegno, a term encompassing fine art, and, in 1588, obtained the position of instructor in the Accademia delle Arti del Disegno in Florence, teaching perspective and chiaroscuro.

In the same year, upon invitation by the Florentine Academy, he presented two lectures, On the Shape, Location, and Size of Dante's Inferno, in an attempt to propose a rigorous cosmological model of Dante's hell. Being inspired by the artistic tradition of the city and the works of the Renaissance artists, Galileo acquired an aesthetic mentality.

While a young teacher at the Accademia, he began a lifelong friendship with the Florentine painter Cigoli.

In 1589, he was appointed to the chair of mathematics in Pisa. In 1591, his father died, and he was entrusted with the care of his younger brother Michelagnolo. In 1592, he moved to the University of Padua where he taught geometry, mechanics, and astronomy until 1610.

During this period, Galileo made significant discoveries in both pure fundamental science (for example, kinematics of motion and astronomy) as well as practical applied science (for

example, strength of materials and pioneering the telescope). His multiple interests included the study of astrology, which at the time was a discipline tied to the studies of mathematics and astronomy.

Astronomy

Kepler's supernova

Tycho Brahe and others had observed the supernova of 1572. Ottavio Brenzoni's letter of 15 January 1605 to Galileo brought the 1572 supernova and the less bright nova of 1601 to Galileo's notice. Galileo observed and discussed Kepler's Supernova in 1604.

Since these new stars displayed no detectable diurnal parallax, Galileo concluded that they were distant stars, and, therefore, disproved the Aristotelian belief in the immutability of the heavens.

Refracting telescope

Galileo's "cannocchiali" telescopes at the Museo Galileo, Florence

Based only on uncertain descriptions of the first practical telescope which Hans Lippershey tried to patent in the Netherlands in 1608, Galileo, in the following year, made a telescope with about 3x magnification. He later made improved versions with up to about 30x magnification.

With a Galilean telescope, the observer could see magnified, upright images on the Earth—it was what is commonly known as a terrestrial telescope or a spyglass.

He could also use it to observe the sky; for a time, he was one of those who could construct telescopes good enough for that purpose. On 25 August 1609, he demonstrated one of his early telescopes, with a magnification of about 8 or 9, to Venetian lawmakers.

His telescopes were also a profitable sideline for Galileo, who sold them to merchants who found them useful both at sea and as items of trade. He published his initial telescopic astronomical observations in March 1610 in a brief treatise entitled Sidereus Nuncius (Starry Messenger).

Moon

On 30 November 1609, Galileo aimed his telescope at the Moon. While not being the first person to observe the Moon through a telescope (English mathematician Thomas Harriot had done it four months before but only saw a "strange spottednesse"), Galileo was the first to deduce the cause of the uneven waning as light occlusion from lunar mountains and craters. In his study, he also made topographical charts, estimating the heights of the mountains.

The Moon was not what was long thought to have been a translucent and perfect sphere, as Aristotle claimed, and hardly the first "planet", an "eternal pearl to magnificently ascend into the heavenly empyrian", as put forth by Dante.

Galileo is sometimes credited with the discovery of the lunar libration in latitude in 1632, although Thomas Harriot or William Gilbert might have done it before.

A friend of Galileo's, the painter Cigoli, included a realistic depiction of the Moon in one of his paintings, though probably used his own telescope to make the observation.

Jupiter's moons

On 7 January 1610, Galileo observed with his telescope what he described at the time as "three fixed stars, totally invisible by their smallness", all close to Jupiter, and lying on a straight line through it.

Observations on subsequent nights showed that the positions of these "stars" relative to Jupiter were changing in a way that would have been inexplicable if they had really been fixed stars.

On 10 January, Galileo noted that one of them had disappeared, an observation which he attributed to its being hidden behind Jupiter.

Within a few days, he concluded that they were orbiting Jupiter: he had discovered three of Jupiter's four largest moons.

He discovered the fourth on 13 January. Galileo named the group of four the Medicean stars, in honour of his future patron, Cosimo II de' Medici, Grand Duke of Tuscany, and Cosimo's three brothers. Later astronomers, however, renamed them Galilean satellites in honour of their discoverer.

These satellites were independently discovered by Simon Marius on 8 January 1610 and are now called Io, Europa, Ganymede, and Callisto, the names given by Marius in his Mundus Iovialis published in 1614.

Map of France presented in 1684, showing the outline of an earlier map (light outline) compared to a new survey conducted

using the moons of Jupiter as an accurate timing reference (heavier outline)

Galileo's observations of the satellites of Jupiter caused a revolution in astronomy: a planet with smaller planets orbiting it did not conform to the principles of Aristotelian cosmology, which held that all heavenly bodies should circle the Earth, and many astronomers and philosophers initially refused to believe that Galileo could have discovered such a thing.

His observations were confirmed by the observatory of Christopher Clavius and he received a hero's welcome when he visited Rome in 1611. Galileo continued to observe the satellites over the next eighteen months, and by mid-1611, he had obtained remarkably accurate estimates for their periods—a feat which Johannes Kepler had believed impossible.

Galileo saw a practical use for his discovery. Determining the east-west position of ships at sea required their clocks be synchronized with clocks at the prime meridian.

Solving this longitude problem had great importance to safe navigation and large prizes were established by Spain and later Holland for its solution.

Since eclipses of the moons he discovered were relatively frequent and their times could be predicted with great accuracy, they could be used to set shipboard clocks and Galileo applied for the prizes.

Observing the moons from a ship proved too difficult, but the method was used for land surveys, including the remapping of France.

Phases of Venus

In 1610 Galileo Galilei observed with his telescope that Venus showed phases, despite remaining near the Sun in Earth's sky (first image). This proved that it orbits the Sun and not Earth, as predicted by Copernicus's heliocentric model and disproved the then conventional geocentric model (second image).

From September 1610, Galileo observed that Venus exhibits a full set of phases similar to that of the Moon. The heliocentric model of the Solar System developed by Nicolaus Copernicus predicted that all phases would be visible since the orbit of Venus around the Sun would cause its illuminated hemisphere to face the Earth when it was on the opposite side of the Sun and to face away from the Earth when it was on the Earth-side of the Sun.

In Ptolemy's geocentric model, it was impossible for any of the planets' orbits to intersect the spherical shell carrying the Sun. Traditionally, the orbit of Venus was placed entirely on the near side of the Sun, where it could exhibit only crescent and new phases.

It was also possible to place it entirely on the far side of the Sun, where it could exhibit only gibbous and full phases.

After Galileo's telescopic observations of the crescent, gibbous and full phases of Venus, the Ptolemaic model became untenable. In the early 17th century, as a result of his discovery, the great majority of astronomers converted to one of the various geo-heliocentric planetary models, such as the Tychonic, Capellan and Extended Capellan models, each either with or without a daily rotating Earth.

These all explained the phases of Venus without the 'refutation' of full heliocentrism's prediction of stellar parallax. Galileo's discovery of the phases of Venus was thus his most empirically practically influential contribution to the two-stage transition from full geocentrism to full heliocentrism via geo-heliocentrism.

Saturn and Neptune

In 1610, Galileo also observed the planet Saturn, and at first mistook its rings for planets, thinking it was a three-bodied system. When he observed the planet later, Saturn's rings were directly oriented at Earth, causing him to think that two of the bodies had disappeared. The rings reappeared when he observed the planet in 1616, further confusing him.

Galileo observed the planet Neptune in 1612. It appears in his notebooks as one of many unremarkable dim stars. He did not realise that it was a planet, but he did note its motion relative to the stars before losing track of it.

Sunspots

Galileo made naked-eye and telescopic studies of sunspots. Their existence raised another difficulty with the unchanging perfection of the heavens as posited in orthodox Aristotelian celestial physics.

An apparent annual variation in their trajectories, observed by Francesco Sizzi and others in 1612–1613, also provided a powerful argument against both the Ptolemaic system and the geoheliocentric system of Tycho Brahe.

A dispute over claimed priority in the discovery of sunspots, and in their interpretation, led Galileo to a long and bitter feud with the Jesuit Christoph Scheiner.

In the middle was Mark Welser, to whom Scheiner had announced his discovery, and who asked Galileo for his opinion. Both of them were unaware of Johannes Fabricius' earlier observation and publication of sunspots.

Milky Way and stars

Galileo observed the Milky Way, previously believed to be nebulous, and found it to be a multitude of stars packed so densely that they appeared from Earth to be clouds. He located many other stars too distant to be visible with the naked eye. He observed the double star Mizar in Ursa Major in 1617.

In the Starry Messenger, Galileo reported that stars appeared as mere blazes of light, essentially unaltered in appearance by the telescope, and contrasted them to planets, which the telescope revealed to be discs. But shortly thereafter, in his Letters on Sunspots, he reported that the telescope revealed the shapes of both stars and planets to be "quite round".

From that point forward, he continued to report that telescopes showed the roundness of stars, and that stars seen through the telescope measured a few seconds of arc in diameter.

He also devised a method for measuring the apparent size of a star without a telescope. As described in his Dialogue Concerning the Two Chief World Systems, his method was to hang a thin rope in his line of sight to the star and measure the maximum distance from which it would wholly obscure the star.

From his measurements of this distance and of the width of the rope, he could calculate the angle subtended by the star at his viewing point.

In his Dialogue, he reported that he had found the apparent diameter of a star of first magnitude to be no more than 5 arcseconds, and that of one of sixth magnitude to be about 5/6 arcseconds. Like most astronomers of his day, Galileo did not recognise that the apparent sizes of stars that he measured were spurious, caused by diffraction and atmospheric distortion, and did not represent the true sizes of stars.

However, Galileo's values were much smaller than previous estimates of the apparent sizes of the brightest stars, such as those made by Brahe, and enabled Galileo to counter anti-Copernican arguments such as those made by Tycho that these stars would have to be absurdly large for their annual parallaxes to be undetectable.

Other astronomers such as Simon Marius, Giovanni Battista Riccioli, and Martinus Hortensius made similar measurements of stars, and Marius and Riccioli concluded the smaller sizes were not small enough to answer Tycho's argument.

Theory of tides

Galileo Galilei, portrait by Domenico Tintoretto

Cardinal Bellarmine had written in 1615 that the Copernican system could not be defended without "a true physical demonstration that the sun does not circle the earth but the earth circles the sun". Galileo considered his theory of the tides to provide such evidence.

This theory was so important to him that he originally intended to call his Dialogue Concerning the Two Chief World Systems the Dialogue on the Ebb and Flow of the Sea. The reference to tides was removed from the title by order of the Inquisition.

For Galileo, the tides were caused by the sloshing back and forth of water in the seas as a point on the Earth's surface sped up and slowed down because of the Earth's rotation on its axis and revolution around the Sun.

He circulated his first account of the tides in 1616, addressed to Cardinal Orsini.

His theory gave the first insight into the importance of the shapes of ocean basins in the size and timing of tides; he correctly accounted, for instance, for the negligible tides halfway along the Adriatic Sea compared to those at the ends. As a general account of the cause of tides, however, his theory was a failure.

If this theory were correct, there would be only one high tide per day. Galileo and his contemporaries were aware of this inadequacy because there are two daily high tides at Venice instead of one, about 12 hours apart.

Galileo dismissed this anomaly as the result of several secondary causes including the shape of the sea, its depth, and other factors.

Albert Einstein later expressed the opinion that Galileo developed his "fascinating arguments" and accepted them uncritically out of a desire for physical proof of the motion of the Earth.

Galileo also dismissed the idea, known from antiquity and by his contemporary Johannes Kepler, that the Moon caused the tides—Galileo also took no interest in Kepler's elliptical orbits of the planets.

Galileo continued to argue in favour of his theory of tides, considering it the ultimate proof of Earth's motion.

Controversy over comets and The Assayer

In 1619, Galileo became embroiled in a controversy with Father Orazio Grassi, professor of mathematics at the Jesuit Collegio Romano. It began as a dispute over the nature of comets, but by the time Galileo had published The Assayer (Il Saggiatore) in 1623, his last salvo in the dispute, it had become a much wider controversy over the very nature of science itself.

The title page of the book describes Galileo as philosopher and "Matematico Primario" of the Grand Duke of Tuscany.

Because The Assayer contains such a wealth of Galileo's ideas on how science should be practised, it has been referred to as his scientific manifesto.

Early in 1619, Father Grassi had anonymously published a pamphlet, An Astronomical Disputation on the Three Comets of the Year 1618, which discussed the nature of a comet that had appeared late in November of the previous year.

Grassi concluded that the comet was a fiery body that had moved along a segment of a great circle at a constant distance from the earth, and since it moved in the sky more slowly than the Moon, it must be farther away than the Moon.

Grassi's arguments and conclusions were criticised in a subsequent article, Discourse on Comets, published under the name of one of Galileo's disciples, a Florentine lawyer named Mario Guiducci, although it had been largely written by Galileo himself.

Galileo and Guiducci offered no definitive theory of their own on the nature of comets, although they did present some tentative conjectures that are now known to be mistaken. (The correct approach to the study of comets had been proposed at the time by Tycho Brahe.)

In its opening passage, Galileo and Guiducci's Discourse gratuitously insulted the Jesuit Christoph Scheiner, and various uncomplimentary remarks about the professors of the Collegio Romano were scattered throughout the work.

The Jesuits were offended, and Grassi soon replied with a polemical tract of his own, The Astronomical and Philosophical Balance, under the pseudonym Lothario Sarsio Sigensano, purporting to be one of his own pupils.

The Assayer was Galileo's devastating reply to the Astronomical Balance. It has been widely recognized as a masterpiece of polemical literature, in which "Sarsi's" arguments are subjected to withering scorn. It was greeted with wide acclaim, and particularly pleased the new pope, Urban VIII, to whom it had been dedicated.

In Rome, in the previous decade, Barberini, the future Urban VIII, had come down on the side of Galileo and the Lincean Academy.

Galileo's dispute with Grassi permanently alienated many Jesuits, and Galileo and his friends were convinced that they were responsible for bringing about his later condemnation, although supporting evidence for this is not conclusive.

Death

Tomb of Galileo, Santa Croce, Florence.

Galileo continued to receive visitors until his death on 8 January 1642, aged 77, after suffering fever and heart palpitations.

The Grand Duke of Tuscany, Ferdinando II, wished to bury him in the main body of the Basilica of Santa Croce, next to the tombs of his father and other ancestors, and to erect a marble mausoleum in his honour.

Middle finger of Galileo's right hand

These plans were dropped, however, after Pope Urban VIII and his nephew, Cardinal Francesco Barberini, protested, because Galileo had been condemned by the Catholic Church for "vehement suspicion of heresy".

He was instead buried in a small room next to the novices' chapel at the end of a corridor from the southern transept of the basilica to the sacristy.

He was reburied in the main body of the basilica in 1737 after a monument had been erected there in his honour; during this move, three fingers and a tooth were removed from his remains.

These fingers are currently on exhibition at the Museo Galileo in Florence, Italy.

About Nikola Tesla

Nikola Tesla, (born July 9/10, 1856, Smiljan, Austrian Empire [now in Croatia]—died January 7, 1943, New York, New York, U.S.), Serbian American inventor and engineer who discovered and patented the rotating magnetic field, the basis of most alternating-current machinery.

He also developed the three-phase system of electric power transmission.

He immigrated to the United States in 1884 and sold the patent rights to his system of alternating-current dynamos, transformers, and motors to George Westinghouse. In 1891 he invented the Tesla coil, an induction coil widely used in radio technology.

Tesla was from a family of Serbian origin. His father was an Orthodox priest; his mother was unschooled but highly intelligent. As he matured, he displayed remarkable imagination and creativity as well as a poetic touch.

Training for an engineering career, he attended the Technical University at Graz, Austria, and the University of Prague.

At Graz he first saw the Gramme dynamo, which operated as a generator and, when reversed, became an electric motor, and he conceived a way to use alternating current to advantage.

Later, at Budapest, he visualized the principle of the rotating magnetic field and developed plans for an induction motor that would become his first step toward the successful utilization of alternating current.

In 1882 Tesla went to work in Paris for the Continental Edison Company, and, while on assignment to Strassburg in 1883, he constructed, after work hours, his first induction motor. Tesla sailed for America in 1884, arriving in New York with four cents in his pocket, a few of his own poems, and calculations for a flying machine.

He first found employment with Thomas Edison, but the two inventors were far apart in background and methods, and their separation was inevitable.

In May 1888 George Westinghouse, head of the Westinghouse Electric Company in Pittsburgh, bought the patent rights to Tesla's polyphase system of alternating-current dynamos, transformers, and motors.

The transaction precipitated a titanic power struggle between Edison's direct-current systems and the Tesla-Westinghouse alternating-current approach, which eventually won out.

Tesla soon established his own laboratory, where his inventive mind could be given free rein. He experimented with shadowgraphs similar to those that later were to be used by Wilhelm Röntgen when he discovered X-rays in 1895.

Tesla's countless experiments included work on a carbon button lamp, on the power of electrical resonance, and on various types of lighting.

In order to allay fears of alternating currents, Tesla gave exhibitions in his laboratory in which he lit lamps by allowing electricity to flow through his body. He was often invited to lecture at home and abroad.

The Tesla coil, which he invented in 1891, is widely used today in radio and television sets and other electronic equipment. That year also marked the date of Tesla's U.S. citizenship.

Westinghouse used Tesla's alternating current system to light the World's Columbian Exposition at Chicago in 1893. This success was a factor in their winning the contract to install the first power machinery at Niagara Falls, which bore Tesla's name and patent numbers. The project carried power to Buffalo by 1896.

In 1898 Tesla announced his invention of a teleautomatic boat guided by remote control. When skepticism was voiced, Tesla proved his claims for it before a crowd in Madison Square Garden.

Nikola Tesla: In Colorado Springs, Colorado, where he stayed from May 1899 until early 1900, Tesla made what he regarded as his most important discovery—terrestrial stationary waves. By this discovery he proved that Earth could be used as a conductor and made to resonate at a certain electrical frequency.

He also lit 200 lamps without wires from a distance of 40 km (25 miles) and created man-made lightning, producing flashes measuring 41 metres (135 feet). At one time he was certain he had received signals from another planet in his Colorado laboratory, a claim that was met with derision in some scientific journals.

Returning to New York in 1900, Tesla began construction on Long Island of a wireless world broadcasting tower, with $150,000 capital from the American Financier J.

Pierpont Morgan. Tesla claimed he secured the loan by assigning 51 percent of his patent rights of telephony and telegraphy to Morgan. He expected to provide worldwide communication and to furnish facilities for sending pictures, messages, weather warnings, and stock reports.

The project was abandoned because of a financial panic, lab our troubles, and Morgan's withdrawal of support. It was Tesla's greatest defeat.

Tesla's work then shifted to turbines and other projects. Because of a lack of funds, his ideas remained in his notebooks, which are still examined by enthusiasts for unexploited clues. In 1915 he was severely disappointed when a report that he and Edison were to share the Nobel Prize proved erroneous.

Tesla was the recipient of the Edison Medal in 1917, the highest honour that the American Institute of Electrical Engineers could bestow.

Tesla allowed himself only a few close friends. Among them were the writers Robert Underwood Johnson, Mark Twain, and Francis Marion Crawford. He was quite impractical in financial matters and an eccentric, driven by compulsions and a progressive germ phobia.

But he had a way of intuitively sensing hidden scientific secrets and employing his inventive talent to prove his hypotheses.

alternating current, abbreviation AC, flow of electric charge that periodically reverses. It starts, say, from zero, grows to a maximum, decreases to zero, reverses, reaches a maximum in

the opposite direction, returns again to the original value, and repeats this cycle indefinitely.

The interval of time between the attainment of a definite value on two successive cycles is called the period, the number of cycles or periods per second is the frequency, and the maximum value in either direction is the amplitude of the alternating current.

Low frequencies, such as 50 and 60 cycles per second (hertz), are used for domestic and commercial power, but alternating currents of frequencies around 100,000,000 cycles per second (100 megahertz) are used in television and those of several thousand megahertz in radar or microwave communication.

Cellular telephones operate at frequencies of about 1,000 megahertz (1 gigahertz).

For decades, alternating current (AC) had the distinct advantage over direct current (DC; a steady flow of electric charge in one direction) of being able to transmit power over large distances without great loss of energy to resistance. The power transmitted is equal to the current times the voltage; however, the power lost is equal to the resistance times the square of the current.

Changing voltages was very difficult with the first DC electric power grids in the late 19th century. Because of the power loss, these grids used low voltages to maintain high current and thus could only transmit usable power over short distances. DC power transmission was soon supplanted by AC systems that transmit power at very high voltages (and correspondingly low current) and easily use transformers to change the voltage.

(However, current DC systems can easily change voltages.) Current AC systems transmit power from generators at hundreds of thousands of volts and use transformers to lower the voltage to 220 volts (as in much of the world) or 120 volts (as in North America) for individual customers.

See also electric current.

Tesla was a godsend to reporters who sought sensational copy but a problem to editors who were uncertain how seriously his futuristic prophecies should be regarded.

Caustic criticism greeted his speculations concerning communication with other planets, his assertions that he could split the Earth like an apple, and his claim of having invented a death ray capable of destroying 10,000 airplanes at a distance of 400 km (250 miles).

After Tesla's death the custodian of alien property impounded his trunks, which held his papers, his diplomas and other honours, his letters, and his laboratory notes.

These were eventually inherited by Tesla's nephew, Sava Kosanovich, and later housed in the Nikola Tesla Museum in Belgrade.

Hundreds filed into New York City's Cathedral of St. John the Divine for his funeral services, and a flood of messages acknowledged the loss of a great genius.

Three Nobel Prize recipients addressed their tribute to "one of the outstanding intellects of the world who paved the way for many of the technological developments of modern times.

About Sigmund Freud

Sigmund Freud (1856 to 1939) was the founding father of psychoanalysis, a method for treating mental illness and also a theory which explains human behavior.

Freud believed that events in our childhood have a great influence on our adult lives, shaping our personality. For example, anxiety originating from traumatic experiences in a person's past is hidden from consciousness, and may cause problems during adulthood (in the form of neuroses).

Thus, when we explain our behavior to ourselves or others (conscious mental activity), we rarely give a true account of our motivation. This is not because we are deliberately lying. While human beings are great deceivers of others; they are even more adept at self-deception.

Freud's life work was dominated by his attempts to find ways of penetrating this often subtle and elaborate camouflage that obscures the hidden structure and processes of personality.

His lexicon has become embedded within the vocabulary of Western society. Words he introduced through his theories are now used by everyday people, such as anal (personality), libido, denial, repression, cathartic, Freudian slip, and neurotic.

The Case Of Anna O

The case of Anna O (real name Bertha Pappenheim) marked a turning point in the career of a young Viennese neuropathologist by the name of Sigmund Freud. It even went on to influence the future direction of psychology as a whole.

Anna O. suffered from hysteria, a condition in which the patient exhibits physical symptoms (e.g., paralysis, convulsions, hallucinations, loss of speech) without an apparent physical cause.

Her doctor (and Freud's teacher) Josef Breuer succeeded in treating Anna by helping her to recall forgotten memories of traumatic events.

During discussions with her, it became apparent that she had developed a fear of drinking when a dog she hated drank from her glass. Her other symptoms originated when caring for her sick father.

She would not express her anxiety for her his illness but did express it later, during psychoanalysis. As soon as she had the opportunity to make these unconscious thoughts conscious her paralysis disappeared.

Breuer discussed the case with his friend Freud. Out of these discussions came the germ of an idea that Freud was to pursue for the rest of his life.

In Studies in Hysteria (1895) Freud proposed that physical symptoms are often the surface manifestations of deeply repressed conflicts.

However, Freud was not just advancing an explanation of a particular illness. Implicitly he was proposing a revolutionary new theory of the human psyche itself.

This theory emerged "bit by bit" as a result of Freud's clinical investigations, and it led him to propose that there were at least three levels of the mind.

The Unconscious Mind

Freud (1900, 1905) developed a topographical model of the mind, whereby he described the features of the mind's structure and function. Freud used the analogy of an iceberg to describe the three levels of the mind.

On the surface is consciousness, which consists of those thoughts that are the focus of our attention now, and this is seen as the tip of the iceberg. The preconscious consists of all which can be retrieved from memory.

The third and most significant region is the unconscious. Here lie the processes that are the real cause of most behavior. Like an iceberg, the most important part of the mind is the part you cannot see.

The unconscious mind acts as a repository, a 'cauldron' of primitive wishes and impulse kept at bay and mediated by the preconscious area.

For example, Freud (1915) found that some events and desires were often too frightening or painful for his patients to acknowledge, and believed such information was locked away in the unconscious mind. This can happen through the process of repression.

Sigmund Freud emphasized the importance of the unconscious mind, and a primary assumption of Freudian theory is that the unconscious mind governs behavior to a greater degree than people suspect.

Indeed, the goal of psychoanalysis is to make the unconscious conscious.

The Psyche

Freud (1923) later developed a more structural model of the mind comprising the entities id, ego, and superego (what Freud called “the psychic apparatus”). These are not physical areas within the brain, but rather hypothetical conceptualizations of important mental functions.

The id, ego, and superego have most commonly been conceptualized as three essential parts of the human personality.

Freud assumed the id operated at an unconscious level according to the pleasure principle (gratification from satisfying basic instincts). The id comprises two kinds of biological instincts (or drives) which Freud called Eros and Thanatos.

Eros, or life instinct, helps the individual to survive; it directs life-sustaining activities such as respiration, eating, and sex (Freud, 1925). The energy created by the life instincts is known as libido.

In contrast, Thanatos or death instinct, is viewed as a set of destructive forces present in all human beings (Freud, 1920). When this energy is directed outward onto others, it is expressed as aggression and violence. Freud believed that Eros is stronger than Thanatos, thus enabling people to survive rather than self-destruct.

The ego develops from the id during infancy. The ego’s goal is to satisfy the demands of the id in a safe a socially acceptable way. In contrast to the id, the ego follows the reality principle as it operates in both the conscious and unconscious mind.

The superego develops during early childhood (when the child identifies with the same sex parent) and is responsible for ensuring moral standards are followed. The superego operates on the morality principle and motivates us to behave in a socially responsible and acceptable manner.

The basic dilemma of all human existence is that each element of the psychic apparatus makes demands upon us that are incompatible with the other two. Inner conflict is inevitable. For example, the superego can make a person feel guilty if rules are not followed.

When there is a conflict between the goals of the id and superego, the ego must act as a referee and mediate this conflict. The ego can deploy various defense mechanisms (Freud, 1894, 1896) to prevent it from becoming overwhelmed by anxiety.

Psychosexual Stages

In the highly repressive “Victorian” society in which Freud lived and worked women, in particular, were forced to repress their sexual needs. In many cases, the result was some form of neurotic illness.

Freud sought to understand the nature and variety of these illnesses by retracing the sexual history of his patients. This was not primarily an investigation of sexual experiences as such.

Far more important were the patient’s wishes and desires, their experience of love, hate, shame, guilt and fear – and how they handled these powerful emotions.

It was this that led to the most controversial part of Freud's work – his theory of psychosexual development and the Oedipus complex.

To be psychologically healthy, we must successfully complete each stage.

Mental abnormality can occur if a stage is not completed successfully and the person becomes 'fixated' in a particular stage. This particular theory shows how adult personality is determined by childhood experiences.

Dream Analysis

Freud (1900) considered dreams to be the royal road to the unconscious as it is in dreams that the ego's defenses are lowered so that some of the repressed material comes through to awareness, albeit in distorted form.

Dreams perform important functions for the unconscious mind and serve as valuable clues to how the unconscious mind operates. On 24 July 1895, Freud had his own dream that was to form the basis of his theory.

He had been worried about a patient, Irma, who was not doing as well in treatment as he had hoped. Freud, in fact, blamed himself for this, and was feeling guilty.

Freud dreamed that he met Irma at a party and examined her. He then saw a chemical formula for a drug that another doctor had given Irma flash before his eyes and realized that her condition was caused by a dirty syringe used by the other doctor.

Freud's guilt was thus relieved.

Freud interpreted this dream as wish-fulfillment. He had wished that Irma's poor condition was not his fault and the dream had fulfilled this wish by informing him that another doctor was at fault. Based on this dream, Freud (1900) went on to propose that a major function of dreams was the fulfillment of wishes.

Freud distinguished between the manifest content of a dream (what the dreamer remembers) and the latent content, the symbolic meaning of the dream (i.e., the underlying wish). The manifest content is often based on the events of the day.

The process whereby the underlying wish is translated into the manifest content is called dreamwork. The purpose of dreamwork is to transform the forbidden wish into a non-threatening form, thus reducing anxiety and allowing us to continue sleeping. Dreamwork involves the process of condensation, displacement, and secondary elaboration.

The process of condensation is the joining of two or more ideas/images into one. For example, a dream about a man may be a dream about both one's father and one's lover. A dream about a house might be the condensation of worries about security as well as worries about one's appearance to the rest of the world.

Displacement takes place when we transform the person or object we are really concerned about to someone else. For example, one of Freud's patients was extremely resentful of his sister-in-law and used to refer to her as a dog, dreamed of strangling a small white dog.

Freud interpreted this as representing his wish to kill his sister-in-law. If the patient would have really dreamed of killing his sister-in-law, he would have felt guilty. The unconscious mind transformed her into a dog to protect him.

Secondary elaboration occurs when the unconscious mind strings together wish-fulfilling images in a logical order of events, further obscuring the latent content. According to Freud, this is why the manifest content of dreams can be in the form of believable events.

In Freud's later work on dreams, he explored the possibility of universal symbols in dreams. Some of these were sexual in nature, including poles, guns, and swords representing the penis and horse riding and dancing representing sexual intercourse.

However, Freud was cautious about symbols and stated that general symbols are more personal rather than universal. A person cannot interpret what the manifest content of a dream symbolized without knowing about the person's circumstances.

"Dream dictionaries", which are still popular now, were a source of irritation to Freud. In an amusing example of the limitations of universal symbols, one of Freud's patients, after dreaming about holding a wriggling fish, said to him "that's a Freudian symbol – it must be a penis!"

Freud explored further, and it turned out that the woman's mother, who was a passionate astrologer and a Pisces, was on the patient's mind because she disapproved of her daughter being in analysis.

It seems more plausible, as Freud suggested, that the fish represented the patient's mother rather than a penis!

Freud's Followers

Freud attracted many followers, who formed a famous group in 1902 called the "Psychological Wednesday Society." The group met every Wednesday in Freud's waiting room. As the organization grew, Freud established an inner circle of devoted followers, the so-called "Committee" (including Sàndor Ferenczi, and Hanns Sachs (standing) Otto Rank, Karl Abraham, Max Eitingon, and Ernest Jones).

At the beginning of 1908, the committee had 22 members and renamed themselves the Vienna Psychoanalytic Society.

Critical Evaluation

Is Freudian psychology supported by evidence? Freud's theory is good at explaining but not predicting behavior (which is one of the goals of science).

For this reason, Freud's theory is unfalsifiable – it can neither be proved true or refuted. For example, the unconscious mind is difficult to test and measure objectively.

Overall, Freud's theory is highly unscientific.

Despite the skepticism of the unconscious mind, cognitive psychology has identified unconscious processes, such as procedural memory (Tulving, 1972), automatic processing (Bargh & Chartrand, 1999; Stroop, 1935), and social psychology has shown the importance of implicit processing (Greenwald & Banaji, 1995). Such empirical findings have demonstrated the role of unconscious processes in human behavior.

However, most of the evidence for Freud's theories are taken from an unrepresentative sample. He mostly studied himself, his patients and only one child (e.g., Little Hans).

The main problem here is that the case studies are based on studying one person in detail, and with reference to Freud, the individuals in question are most often middle-aged women from Vienna (i.e., his patients).

This makes generalizations to the wider population (e.g., the whole world) difficult. However, Freud thought this unimportant, believing in only a qualitative difference between people.

Freud may also have shown research bias in his interpretations – he may have only paid attention to information which supported his theories, and ignored information and other explanations that did not fit them.

However, Fisher & Greenberg (1996) argue that Freud's theory should be evaluated in terms of specific hypotheses rather than as a whole.

They concluded that there is evidence to support Freud's concepts of oral and anal personalities and some aspects of his ideas on depression and paranoia.

They found little evidence of the Oedipal conflict and no support for Freud's views on women's sexuality and how their development differs from men'.

Biography

Early life and education

Freud's birthplace, a rented room in a locksmith's house, Freiberg, Austrian Empire (later Příbor, Czech Republic)

Freud (aged 16) and his mother, Amalia, in 1872

Sigmund Freud was born to Ashkenazi Jewish parents in the Moravian town of Freiberg, in the Austrian Empire (now Příbor, Czech Republic), the first of eight children. Both of his parents were from Galicia, a historic province straddling modern-day West Ukraine and southeast Poland.

His father, Jakob Freud (1815–1896), a wool merchant, had two sons, Emanuel (1833–1914) and Philipp (1836–1911), by his first marriage.

Jakob's family were Hasidic Jews and, although Jakob himself had moved away from the tradition, he came to be known for his Torah study. He and Freud's mother, Amalia Nathansohn, who was 20 years younger and his third wife, were married by Rabbi Isaac Noah Mannheimer on 29 July 1855.

They were struggling financially and living in a rented room, in a locksmith's house at Schlossergasse 117 when their son Sigmund was born. He was born with a caul, which his mother saw as a positive omen for the boy's future.

In 1859, the Freud family left Freiberg. Freud's half-brothers immigrated to Manchester, England, parting him from the "inseparable" playmate of his early childhood, Emanuel's son, John.

Jakob Freud took his wife and two children (Freud's sister, Anna, was born in 1858; a brother, Julius born in 1857, had died in infancy) firstly to Leipzig and then in 1860 to Vienna where

four sisters and a brother were born: Rosa (b. 1860), Marie (b. 1861), Adolfine (b. 1862), Paula (b. 1864), Alexander (b. 1866). In 1865, the nine-year-old Freud entered the Leopoldstädter Kommunal-Realgymnasium, a prominent high school.

He proved to be an outstanding pupil and graduated from the Matura in 1873 with honors. He loved literature and was proficient in German, French, Italian, Spanish, English, Hebrew, Latin and Greek.

Freud entered the University of Vienna at age 17.

He had planned to study law, but joined the medical faculty at the university, where his studies included philosophy under Franz Brentano, physiology under Ernst Brücke, and zoology under Darwinist professor Carl Claus.

In 1876, Freud spent four weeks at Claus's zoological research station in Trieste, dissecting hundreds of eels in an inconclusive search for their male reproductive organs.

In 1877, Freud moved to Ernst Brücke's physiology laboratory where he spent six years comparing the brains of humans and other vertebrates with those of frogs and invertebrates such as crayfish and lampreys.

His research work on the biology of nervous tissue proved seminal for the subsequent discovery of the neuron in the 1890s. Freud's research work was interrupted in 1879 by the obligation to undertake a year's compulsory military service. The lengthy downtimes enabled him to complete a commission to translate four essays from John Stuart Mill's collected works. He graduated with an MD in March 1881.

Early career and marriage

In 1882, Freud began his medical career at Vienna General Hospital. His research work in cerebral anatomy led to the publication in 1884 of an influential paper on the palliative effects of cocaine, and his work on aphasia would form the basis of his first book On Aphasia: A Critical Study, published in 1891.

Over a three-year period, Freud worked in various departments of the hospital. His time spent in Theodor Meynert's psychiatric clinic and as a locum in a local asylum led to an increased interest in clinical work. His substantial body of published research led to his appointment as a university lecturer or docent in neuropathology in 1885, a non-salaried post but one which entitled him to give lectures at the University of Vienna.

In 1886, Freud resigned his hospital post and entered private practice specializing in "nervous disorders". The same year he married Martha Bernays, the granddaughter of Isaac Bernays, a chief rabbi in Hamburg. Freud was, as an atheist, dismayed at the requirement in Austria for a Jewish religious ceremony and briefly considered, before dismissing, the prospect of joining the Protestant 'Confession' to avoid one.

In the event a civil ceremony took place on 13 September and a religious ceremony the following day with Freud having been hastily tutored in the Hebrew prayers.

The Freuds had six children: Mathilde (b. 1887), Jean-Martin (b. 1889), Oliver (b. 1891), Ernst (b. 1892), Sophie (b. 1893), and Anna (b. 1895).

From 1891 until they left Vienna in 1938, Freud and his family lived in an apartment at Berggasse 19, near Innere Stadt, a historical district of Vienna.

In 1896, Minna Bernays, Martha Freud's sister, became a permanent member of the Freud household after the death of her fiancé. The close relationship she formed with Freud led to rumours, started by Carl Jung, of an affair.

The discovery of a Swiss hotel guest-book entry for 13 August 1898, signed by Freud whilst travelling with his sister-in-law, has been presented as evidence of the affair.

Freud began smoking tobacco at age 24; initially a cigarette smoker, he became a cigar smoker. He believed smoking enhanced his capacity to work and that he could exercise self-control in moderating it.

Despite health warnings from colleague Wilhelm Fliess, he remained a smoker, eventually developing a buccal cancer. Freud suggested to Fliess in 1897 that addictions, including that to tobacco, were substitutes for masturbation, "the one great habit."

Freud had greatly admired his philosophy tutor, Brentano, who was known for his theories of perception and introspection. Brentano discussed the possible existence of the unconscious mind in his Psychology from an Empirical Standpoint (1874). Although Brentano denied its existence, his discussion of the unconscious probably helped introduce Freud to the concept. Freud owned and made use of Charles Darwin's major evolutionary writings, and was also influenced by Eduard von Hartmann's The Philosophy of the Unconscious (1869).

Other texts of importance to Freud were by Fechner and Herbart, with the latter's Psychology as Science arguably considered to be of underrated significance in this respect.

Freud also drew on the work of Theodor Lipps, who was one of the main contemporary theorists of the concepts of the unconscious and empathy.

Though Freud was reluctant to associate his psychoanalytic insights with prior philosophical theories, attention has been drawn to analogies between his work and that of both Schopenhauer and Nietzsche.

In 1908, Freud said that he occasionally read Nietzsche, and was strongly fascinated by his writings, but did not study him, because he found Nietzsche's "intuitive insights" resembled too much his own work at the time, and also because he was overwhelmed by the "wealth of ideas" he encountered when he read Nietzsche. Freud sometimes would deny the influence of Nietzsche's ideas.

One historian quotes Peter L. Rudnytsky, who says that based on Freud's correspondence with his adolescent friend Eduard Silberstein, Freud read Nietzsche's The Birth of Tragedy and probably the first two of the Untimely Meditations when he was seventeen.

In 1900, the year of Nietzsche's death, Freud bought his collected works; he told his friend, Fliess, that he hoped to find in Nietzsche's works "the words for much that remains mute in me." Later, he said he had not yet opened them.

Freud came to treat Nietzsche's writings "as texts to be resisted far more than to be studied." His interest in philosophy declined after he had decided on a career in neurology.

Freud read William Shakespeare in English throughout his life, and it has been suggested that his understanding of human psychology may have been partially derived from Shakespeare's plays.

Freud's Jewish origins and his allegiance to his secular Jewish identity were of significant influence in the formation of his intellectual and moral outlook, especially concerning his intellectual non-conformism, as he pointed out in his Autobiographical Study.

They would also have a substantial effect on the content of psychoanalytic ideas, particularly in respect of their common concerns with depth interpretation and "the bounding of desire by law".

Relationship with Fliess

During the formative period of his work, Freud valued and came to rely on the intellectual and emotional support of his friend Wilhelm Fliess, a Berlin-based ear, nose, and throat specialist whom he had first met in 1887. Both men saw themselves as isolated from the prevailing clinical and theoretical mainstream because of their ambitions to develop radical new theories of sexuality.

Fliess developed highly eccentric theories of human biorhythms and a nasogenital connection which are today considered pseudoscientific.

He shared Freud's views on the importance of certain aspects of sexuality – masturbation, coitus interruptus, and the use of condoms – in the etiology of what was then called the "actual neuroses," primarily neurasthenia and certain physically manifested anxiety symptoms.

They maintained an extensive correspondence from which Freud drew on Fliess's speculations on infantile sexuality and bisexuality to elaborate and revise his own ideas. His first attempt at a systematic theory of the mind, his Project for a Scientific Psychology, was developed as a metapsychology with Fliess as interlocutor.

However, Freud's efforts to build a bridge between neurology and psychology were eventually abandoned after they had reached an impasse, as his letters to Fliess reveal, though some ideas of the Project were to be taken up again in the concluding chapter of The Interpretation of Dreams.

Freud had Fliess repeatedly operate on his nose and sinuses to treat "nasal reflex neurosis", and subsequently referred his patient Emma Eckstein to him. According to Freud, her history of symptoms included severe leg pains with consequent restricted mobility, as well as stomach and menstrual pains.

These pains were, according to Fliess's theories, caused by habitual masturbation which, as the tissue of the nose and genitalia were linked, was curable by removal of part of the middle turbinate. Fliess's surgery proved disastrous, resulting in profuse, recurrent nasal bleeding; he had left a half-metre of gauze in Eckstein's nasal cavity whose subsequent removal left her permanently disfigured.

At first, though aware of Fliess's culpability and regarding the remedial surgery in horror, Freud could bring himself only to intimate delicately in his correspondence with Fliess the nature of his disastrous role, and in subsequent letters maintained a tactful silence on the matter or else returned to the face-saving topic of Eckstein's hysteria.

Freud ultimately, in light of Eckstein's history of adolescent self-cutting and irregular nasal (and menstrual) bleeding, concluded that Fliess was "completely without blame", as Eckstein's post-operative haemorrhages were hysterical "wish-bleedings" linked to "an old wish to be loved in her illness" and triggered as a means of "rearousing [Freud's] affection".

Eckstein nonetheless continued her analysis with Freud. She was restored to full mobility and went on to practice psychoanalysis herself.

Freud, who had called Fliess "the Kepler of biology", later concluded that a combination of a homoerotic attachment and the residue of his "specifically Jewish mysticism" lay behind his loyalty to his Jewish friend and his consequent overestimation of both his theoretical and clinical work.

Their friendship came to an acrimonious end with Fliess angry at Freud's unwillingness to endorse his general theory of sexual periodicity and accusing him of collusion in the plagiarism of his work.

After Fliess failed to respond to Freud's offer of collaboration over the publication of his Three Essays on the Theory of Sexuality in 1906, their relationship came to an end.

Development of psychoanalysis

In October 1885, Freud went to Paris on a three-month fellowship to study with Jean-Martin Charcot, a renowned neurologist who was conducting scientific research into hypnosis.

He was later to recall the experience of this stay as catalytic in turning him toward the practice of medical psychopathology and away from a less financially promising career in neurology research. Charcot specialized in the study of hysteria and susceptibility to hypnosis, which he frequently demonstrated with patients on stage in front of an audience.

Once he had set up in private practice back in Vienna in 1886, Freud began using hypnosis in his clinical work. He adopted the approach of his friend and collaborator, Josef Breuer, in a type of hypnosis that was different from the French methods he had studied, in that it did not use suggestion.

The treatment of one particular patient of Breuer's proved to be transformative for Freud's clinical practice. Described as Anna O., she was invited to talk about her symptoms while under hypnosis (she would coin the phrase "talking cure" for her treatment).

In the course of talking in this way, her symptoms became reduced in severity as she retrieved memories of traumatic incidents associated with their onset.

The inconsistent results of Freud's early clinical work eventually led him to abandon hypnosis, having concluded that more consistent and effective symptom relief could be achieved

by encouraging patients to talk freely, without censorship or inhibition, about whatever ideas or memories occurred to them.

In conjunction with this procedure, which he called "free association", Freud found that patients' dreams could be fruitfully analyzed to reveal the complex structuring of unconscious material and to demonstrate the psychic action of repression which, he had concluded, underlay symptom formation.

By 1896 he was using the term "psychoanalysis" to refer to his new clinical method and the theories on which it was based.

Freud's development of these new theories took place during a period in which he experienced heart irregularities, disturbing dreams and periods of depression, a "neurasthenia" which he linked to the death of his father in 1896 and which prompted a "self-analysis" of his own dreams and memories of childhood.

His explorations of his feelings of hostility to his father and rivalrous jealousy over his mother's affections led him to fundamentally revise his theory of the origin of the neuroses.

Based on his early clinical work, Freud postulated that unconscious memories of sexual molestation in early childhood were a necessary precondition for psychoneuroses (hysteria and obsessional neurosis), a formulation now known as Freud's seduction theory.

In the light of his self-analysis, Freud abandoned the theory that every neurosis can be traced back to the effects of infantile sexual abuse, now arguing that infantile sexual scenarios still had a causative function, but it did not matter

whether they were real or imagined and that in either case, they became pathogenic only when acting as repressed memories.

This transition from the theory of infantile sexual trauma as a general explanation of how all neuroses originate to one that presupposes autonomous infantile sexuality provided the basis for Freud's subsequent formulation of the theory of the Oedipus complex.

Freud described the evolution of his clinical method and set out his theory of the psychogenetic origins of hysteria, demonstrated in several case histories, in Studies on Hysteria published in 1895 (co-authored with Josef Breuer).

In 1899, he published The Interpretation of Dreams in which, following a critical review of existing theory, Freud gives detailed interpretations of his own and his patients' dreams in terms of wish-fulfillments made subject to the repression and censorship of the "dream-work".

He then sets out the theoretical model of mental structure (the unconscious, pre-conscious and conscious) on which this account is based. An abridged version, On Dreams, was published in 1901.

In works that would win him a more general readership, Freud applied his theories outside the clinical setting in The Psychopathology of Everyday Life (1901) and Jokes and their Relation to the Unconscious (1905). In Three Essays on the Theory of Sexuality, published in 1905, Freud elaborates his theory of infantile sexuality, describing its "polymorphous perverse" forms and the functioning of the "drives", to which it gives rise, in the formation of sexual identity.

The same year he published Fragment of an Analysis of a Case of Hysteria, which became one of his more famous and controversial case studies.

Known as the 'Dora' case study, for Freud it was illustrative of hysteria as a symptom and contributed to his understanding of the importance of transference as a clinical phenomenon. In other of his early case studies Freud set out to describe the symptomatology of obsessional neurosis in the case of the Rat man, and phobia in the case of Little Hans.

Transference is the process by which patients displace onto their analyst feelings and ideas which derive from previous figures in their lives. Transference was first seen as a regrettable phenomenon that interfered with the recovery of repressed memories and disturbed patients' objectivity, but by 1912, Freud had come to see it as an essential part of the therapeutic process.

About Isaac Newton

Isaac Newton (1642–1727) is best known for having invented the calculus in the mid to late 1660s (most of a decade before Leibniz did so independently, and ultimately more influentially) and for having formulated the theory of universal gravity — the latter in his Principia, the single most important work in the transformation of early modern natural philosophy into modern physical science.

Yet he also made major discoveries in optics beginning in the mid-1660s and reaching across four decades; and during the course of his 60 years of intense intellectual activity he put no less effort into chemical and alchemical research and into

theology and biblical studies than he put into mathematics and physics. He became a dominant figure in Britain almost immediately following publication of his Principia in 1687, with the consequence that “Newtonianism” of one form or another had become firmly rooted there within the first decade of the eighteenth century.

His influence on the continent, however, was delayed by the strong opposition to his theory of gravity expressed by such leading figures as Christiaan Huygens and Leibniz, both of whom saw the theory as invoking an occult power of action at a distance in the absence of Newton's having proposed a contact mechanism by means of which forces of gravity could act.

As the promise of the theory of gravity became increasingly substantiated, starting in the late 1730s but especially during the 1740s and 1750s, Newton became an equally dominant figure on the continent, and “Newtonianism,” though perhaps in more guarded forms, flourished there as well.

What physics textbooks now refer to as “Newtonian mechanics” and “Newtonian science” consists mostly of results achieved on the continent between 1740 and 1800.

Newton's life naturally divides into four parts: the years before he entered Trinity College, Cambridge in 1661; his years in Cambridge before the Principia was published in 1687; a period of almost a decade immediately following this publication, marked by the renown it brought him and his increasing disenchantment with Cambridge; and his final three decades in London, for most of which he was Master of the Mint.

While he remained intellectually active during his years in London, his legendary advances date almost entirely from his years in Cambridge. Nevertheless, save for his optical papers of the early 1670s and the first edition of the Principia, all his works published before he died fell within his years in London.

Newton's Early Years

Newton was born into a Puritan family in Woolsthorpe, a small village in Linconshire near Grantham, on 25 December 1642 (old calendar), a few days short of one year after Galileo died. Isaac's father, a farmer, died two months before Isaac was born.

When his mother Hannah married the 63-year-old Barnabas Smith three years later and moved to her new husband's residence, Isaac was left behind with his maternal grandparents.

(Isaac learned to read and write from his maternal grandmother and mother, both of whom, unlike his father, were literate.) Hannah returned to Woolsthorpe with three new children in 1653, after Smith died. Two years later Isaac went to boarding school in Grantham, returning full time to manage the farm, not very successfully, in 1659.

Hannah's brother, who had received an M.A. from Cambridge, and the headmaster of the Grantham school then persuaded his mother that Isaac should prepare for the university.

After further schooling at Grantham, he entered Trinity College in 1661, somewhat older than most of his classmates.

These years of Newton's youth were the most turbulent in the history of England. The English Civil War had begun in 1642, King Charles was beheaded in 1649, Oliver Cromwell ruled as lord protector from 1653 until he died in 1658, followed by his son Richard from 1658 to 1659, leading to the restoration of the monarchy under Charles II in 1660.

How much the political turmoil of these years affected Newton and his family is unclear, but the effect on Cambridge and other universities was substantial, if only through unshackling them for a period from the control of the Anglican Catholic Church.

The return of this control with the restoration was a key factor inducing such figures as Robert Boyle to turn to Charles II for support for what in 1660 emerged as the Royal Society of London.

The intellectual world of England at the time Newton matriculated to Cambridge was thus very different from what it was when he was born.

Newton's Years at Cambridge Prior to Principia

Newton's initial education at Cambridge was classical, focusing (primarily through secondary sources) on Aristotlean rhetoric, logic, ethics, and physics.

By 1664, Newton had begun reaching beyond the standard curriculum, reading, for example, the 1656 Latin edition of Descartes's Opera philosophica, which included the Meditations, Discourse on Method, the Dioptrics, and the Principles of Philosophy.

By early 1664 he had also begun teaching himself mathematics, taking notes on works by Oughtred, Viète, Wallis, and Descartes — the latter via van Schooten's Latin translation, with commentary, of the Géométrie. Newton spent all but three months from the summer of 1665 until the spring of 1667 at home in Woolsthorpe when the university was closed because of the plague.

This period was his so-called annus mirabilis. During it, he made his initial experimental discoveries in optics and developed (independently of Huygens's treatment of 1659) the mathematical theory of uniform circular motion, in the process noting the relationship between the inverse-square and Kepler's rule relating the square of the planetary periods to the cube of their mean distance from the Sun.

Even more impressively, by late 1666 he had become de facto the leading mathematician in the world, having extended his earlier examination of cutting-edge problems into the discovery of the calculus, as presented in his tract of October 1666.

He returned to Trinity as a Fellow in 1667, where he continued his research in optics, constructing his first reflecting telescope in 1669, and wrote a more extended tract on the calculus "De Analysi per Æquations Numero Terminorum Infinitas" incorporating new work on infinite series. On the basis of this tract Isaac Barrow recommended Newton as his replacement as Lucasian Professor of Mathematics, a position he assumed in October 1669, four and a half years after he had received his Bachelor of Arts.

Over the course of the next fifteen years as Lucasian Professor Newton presented his lectures and carried on research in a variety of areas. By 1671 he had completed most of a treatise length account of the calculus, which he then found no one would publish.

This failure appears to have diverted his interest in mathematics away from the calculus for some time, for the mathematical lectures he registered during this period mostly concern algebra.

(During the early 1680s he undertook a critical review of classical texts in geometry, a review that reduced his view of the importance of symbolic mathematics.) His lectures from 1670 to 1672 concerned optics, with a large range of experiments presented in detail.

Newton went public with his work in optics in early 1672, submitting material that was read before the Royal Society and then published in the Philosophical Transactions of the Royal Society. This led to four years of exchanges with various figures who challenged his claims, including both Robert Hooke and Christiaan Huygens — exchanges that at times exasperated Newton to the point that he chose to withdraw from further public exchanges in natural philosophy.

Before he largely isolated himself in the late 1670s, however, he had also engaged in a series of sometimes long exchanges in the mid-1670s, most notably with John Collins (who had a copy of “De Analysi”) and Leibniz, concerning his work on the calculus. So, though they remained unpublished, Newton's advances in mathematics scarcely remained a secret.

This period as Lucasian Professor also marked the beginning of his more private researches in alchemy and theology. Newton purchased chemical apparatus and treatises in alchemy in 1669, with experiments in chemistry extending across this entire period.

The issue of the vows Newton might have to take in conjunction with the Lucasian Professorship also appears to have precipitated his study of the doctrine of the Trinity, which opened the way to his questioning the validity of a good deal more doctrine central to the Roman and Anglican Churches.

Newton showed little interest in orbital astronomy during this period until Hooke initiated a brief correspondence with him in an effort to solicit material for the Royal Society at the end of November 1679, shortly after Newton had returned to Cambridge following the death of his mother.

Among the several problems Hooke proposed to Newton was the question of the trajectory of a body under an inverse-square central force:

It now remaines to know the proprietys of a curve Line (not circular nor concentricall) made by a centrall attractive power which makes the velocitys of Descent from the tangent Line or equall straight motion at all Distances in a Duplicate proportion to the Distances Reciprocally taken. I doubt not but that by your excellent method you will easily find out what the Curve must be, and it proprietys, and suggest a physicall Reason of this proportion.

Newton apparently discovered the systematic relationship between conic-section trajectories and inverse-square central

forces at the time, but did not communicate it to anyone, and for reasons that remain unclear did not follow up this discovery until Halley, during a visit in the summer of 1684, put the same question to him. His immediate answer was, an ellipse; and when he was unable to produce the paper on which he had made this determination, he agreed to forward an account to Halley in London.

Newton fulfilled this commitment in November by sending Halley a nine-folio-page manuscript, "De Motu Corporum in Gyrum" ("On the Motion of Bodies in Orbit"), which was entered into the Register of the Royal Society in early December 1684.

The body of this tract consists of ten deduced propositions — three theorems and seven problems — all of which, along with their corollaries, recur in important propositions in the Principia.

Save for a few weeks away from Cambridge, from late 1684 until early 1687, Newton concentrated on lines of research that expanded the short ten-proposition tract into the 500 page Principia, with its 192 derived propositions.

Initially the work was to have a two book structure, but Newton subsequently shifted to three books, and replaced the original version of the final book with one more mathematically demanding.

The manuscript for Book 1 was sent to London in the spring of 1686, and the manuscripts for Books 2 and 3, in March and April 1687, respectively.

The roughly three hundred copies of the Principia came off the press in the summer of 1687, thrusting the 44-year-old Newton into the forefront of natural philosophy and forever ending his life of comparative isolation.

Newton's Final Years at Cambridge

The years between the publication of the Principia and Newton's permanent move to London in 1696 were marked by his increasing disenchantment with his situation in Cambridge.

In January 1689, following the Glorious Revolution at the end of 1688, he was elected to represent Cambridge University in the Convention Parliament, which he did until January 1690.

During this time, he formed friendships with John Locke and Nicolas Fatio de Duillier, and in the summer of 1689 he finally met Christiaan Huygens face to face for two extended discussions.

Perhaps because of disappointment with Huygens not being convinced by the argument for universal gravity, in the early 1690s Newton initiated a radical rewriting of the Principia.

During these same years he wrote (but withheld) his principal treatise in alchemy, Praxis; he corresponded with Richard Bentley on religion and allowed Locke to read some of his writings on the subject; he once again entered into an effort to put his work on the calculus in a form suitable for publication; and he carried out experiments on diffraction with the intent of completing his Opticks, only to withhold the manuscript from publication because of dissatisfaction with its treatment of diffraction.

The radical revision of the Principia became abandoned by 1693, during the middle of which Newton suffered, by his own testimony, what in more recent times would be called a nervous breakdown.

In the two years following his recovery that autumn, he continued his experiments in chymistry and he put substantial effort into trying to refine and extend the gravity-based theory of the lunar orbit in the Principia, but with less success than he had hoped.

Throughout these years Newton showed interest in a position of significance in London, but again with less success than he had hoped until he accepted the relatively minor position of Warden of the Mint in early 1696, a position he held until he became Master of the Mint at the end of 1699.

He again represented Cambridge University in Parliament for 16 months, beginning in 1701, the year in which he resigned his Fellowship at Trinity College and the Lucasian Professorship. He was elected President of the Royal Society in 1703 and was knighted by Queen Anne in 1705.

Newton's Years in London and His Final Years

Newton thus became a figure of imminent authority in London over the rest of his life, in face-to-face contact with individuals of power and importance in ways that he had not known in his Cambridge years.

His everyday home life changed no less dramatically when his extraordinarily vivacious teenage niece, Catherine Barton, the daughter of his half-sister Hannah, moved in with him shortly

after he moved to London, staying until she married John Conduitt in 1717, and after that remaining in close contact.

(It was through her and her husband that Newton's papers came down to posterity.) Catherine was socially prominent among the powerful and celebrated among the literati for the years before she married, and her husband was among the wealthiest men of London.

The London years saw Newton embroiled in some nasty disputes, probably made the worse by the ways in which he took advantage of his position of authority in the Royal Society.

In the first years of his Presidency he became involved in a dispute with John Flamsteed in which he and Halley, long ill-disposed toward the Flamsteed, violated the trust of the Royal Astronomer, turning him into a permanent enemy. Ill feelings between Newton and Leibniz had been developing below the surface from even before Huygens had died in 1695, and they finally came to a head in 1710 when John Keill accused Leibniz in the Philosophical Transactions of having plagiarized the calculus from Newton and Leibniz, a Fellow of the Royal Society since 1673, demanded redress from the Society.

The Society's 1712 published response was anything but redress. Newton not only was a dominant figure in this response, but then published an outspoken anonymous review of it in 1715 in the Philosophical Transactions.

Leibniz and his colleagues on the Continent had never been comfortable with the Principia and its implication of action at a distance.

With the priority dispute this attitude turned into one of open hostility toward Newton's theory of gravity — a hostility that was matched in its blindness by the fervor of acceptance of the theory in England.

The public elements of the priority dispute had the effect of expanding a schism between Newton and Leibniz into a schism between the English associated with the Royal Society and the group who had been working with Leibniz on the calculus since the 1690s, including most notably Johann Bernoulli, and this schism in turn transformed into one between the conduct of science and mathematics in England versus the Continent that persisted long after Leibniz died in 1716.

Although Newton obviously had far less time available to devote to solitary research during his London years than he had had in Cambridge, he did not entirely cease to be productive. The first (English) edition of his Opticks finally appeared in 1704, appended to which were two mathematical treatises, his first work on the calculus to appear in print.

This edition was followed by a Latin edition in 1706 and a second English edition in 1717, each containing important Queries on key topics in natural philosophy beyond those in its predecessor. Other earlier work in mathematics began to appear in print, including a work on algebra, Arithmetica Universalis, in 1707 and “De Analysi” and a tract on finite differences, “Methodis differentialis” in 1711.

The second edition of the Principia, on which Newton had begun work at the age of 66 in 1709, was published in 1713, with a third edition in 1726.

Though the original plan for a radical restructuring had long been abandoned, the fact that virtually every page of the Principia received some modifications in the second edition shows how carefully Newton, often prodded by his editor Roger Cotes, reconsidered everything in it; and important parts were substantially rewritten not only in response to Continental criticisms, but also because of new data, including data from experiments on resistance forces carried out in London.

Focused effort on the third edition began in 1723, when Newton was 80 years old, and while the revisions are far less extensive than in the second edition, it does contain substantive additions and modfications, and it surely has claim to being the edition that represents his most considered views.

Newton died on 20 March 1727 at the age of 84.

His contemporaries' conception of him nevertheless continued to expand as a consequence of various posthumous publications, including The Chronology of Ancient Kingdoms Amended (1728); the work originally intended to be the last book of the Principia, The System of the World (1728, in both English and Latin); Observations upon the Prophecies of Daniel and the Apocalypse of St. John (1733); A Treatise of the Method of Fluxions and Infinite Series (1737); A Dissertation upon the Sacred Cubit of the Jews (1737), and Four Letters from Sir Isaac Newton to Doctor Bentley concerning Some Arguments in Proof of a Deity (1756).

Even then, however, the works that had been published represented only a limited fraction of the total body of papers that had been left in the hands of Catherine and John Conduitt.

The five volume collection of Newton's works edited by Samuel Horsley (1779–85) did not alter this situation. Through the marriage of the Conduitts' daughter Catherine and subsequent inheritance, this body of papers came into the possession of Lord Portsmouth, who agreed in 1872 to allow it to be reviewed by scholars at Cambridge University (John Couch Adams, George Stokes, H. R. Luard, and G. D. Liveing).

They issued a catalogue in 1888, and the university then retained all the papers of a scientific character. With the notable exception of W. W. Rouse Ball, little work was done on the scientific papers before World War II.

The remaining papers were returned to Lord Portsmouth, and then ultimately sold at auction in 1936 to various parties. Serious scholarly work on them did not get underway until the 1970s, and much remains to be done on them.

Newton's Work and Influence

Three factors stand in the way of giving an account of Newton's work and influence. First is the contrast between the public Newton, consisting of publications in his lifetime and in the decade or two following his death, and the private Newton, consisting of his unpublished work in math and physics, his efforts in chymistry — that is, the 17th century blend of alchemy and chemistry — and his writings in radical theology — material that has become public mostly since World War II.

Only the public Newton influenced the eighteenth and early nineteenth centuries, yet any account of Newton himself confined to this material can at best be only fragmentary.

Second is the contrast, often shocking, between the actual content of Newton's public writings and the positions attributed to him by others, including most importantly his popularizers.

The term “Newtonian” refers to several different intellectual strands unfolding in the eighteenth century, some of them tied more closely to Voltaire, Pemberton, and Maclaurin — or for that matter to those who saw themselves as extending his work, such as Clairaut, Euler, d'Alembert, Lagrange, and Laplace — than to Newton himself.

Third is the contrast between the enormous range of subjects to which Newton devoted his full concentration at one time or another during the 60 years of his intellectual career — mathematics, optics, mechanics, astronomy, experimental chemistry, alchemy, and theology — and the remarkably little information we have about what drove him or his sense of himself.

Biographers and analysts who try to piece together a unified picture of Newton and his intellectual endeavors often end up telling us almost as much about themselves as about Newton.

Compounding the diversity of the subjects to which Newton devoted time are sharp contrasts in his work within each subject.

Optics and orbital mechanics both fall under what we now call physics, and even then they were seen as tied to one another, as indicated by Descartes' first work on the subject, Le Monde, ou Traité de la lumierè.

Nevertheless, two very different “Newtonian” traditions in physics arose from Newton's Opticks and Principia: from his Opticks a tradition centered on meticulous experimentation and from his Principia a tradition centered on mathematical theory.

The most important element common to these two was Newton's deep commitment to having the empirical world serve not only as the ultimate arbiter, but also as the sole basis for adopting provisional theory.

Throughout all of this work he displayed distrust of what was then known as the method of hypotheses – putting forward hypotheses that reach beyond all known phenomena and then testing them by deducing observable conclusions from them.

Newton insisted instead on having specific phenomena decide each element of theory, with the goal of limiting the provisional aspect of theory as much as possible to the step of inductively generalizing from the specific phenomena.

This stance is perhaps best summarized in his fourth Rule of Reasoning, added in the third edition of the Principia, but adopted as early as his Optical Lectures of the 1670s:

In experimental philosophy, propositions gathered from phenomena by induction should be taken to be either exactly or very nearly true notwithstanding any contrary hypotheses, until yet other phenomena make such propositions either more exact or liable to exceptions.

This rule should be followed so that arguments based on induction may not be nullified by hypotheses.

Such a commitment to empirically driven science was a hallmark of the Royal Society from its very beginnings, and one can find it in the research of Kepler, Galileo, Huygens, and in the experimental efforts of the Royal Academy of Paris.

Newton, however, carried this commitment further first by eschewing the method of hypotheses and second by displaying in his Principia and Opticks how rich a set of theoretical results can be secured through well-designed experiments and mathematical theory designed to allow inferences from phenomena.

The success of those after him in building on these theoretical results completed the process of transforming natural philosophy into modern empirical science.

Newton's commitment to having phenomena decide the elements of theory required questions to be left open when no available phenomena could decide them.

Newton contrasted himself most strongly with Leibniz in this regard at the end of his anonymous review of the Royal Society's report on the priority dispute over the calculus:

It must be allowed that these two Gentlemen differ very much in Philosophy.

The one proceeds upon the Evidence arising from Experiments and Phenomena, and stops where such Evidence is wanting; the other is taken up with Hypotheses, and propounds them, not to be examined by Experiments, but to be believed without Examination.

The one for want of Experiments to decide the Question, doth not affirm whether the Cause of Gravity be Mechanical or not Mechanical; the other that it is a perpetual Miracle if it be not Mechanical.

Newton could have said much the same about the question of what light consists of, waves or particles, for while he felt that the latter was far more probable, he saw it still not decided by any experiment or phenomenon in his lifetime.

Leaving questions about the ultimate cause of gravity and the constitution of light open was the other factor in his work driving a wedge between natural philosophy and empirical science.

The many other areas of Newton's intellectual endeavors made less of a difference to eighteenth century philosophy and science. In mathematics, Newton was the first to develop a full range of algorithms for symbolically determining what we now call integrals and derivatives, but he subsequently became fundamentally opposed to the idea, championed by Leibniz, of transforming mathematics into a discipline grounded in symbol manipulation.

Newton thought the only way of rendering limits rigorous lay in extending geometry to incorporate them, a view that went entirely against the tide in the development of mathematics in the eighteenth and nineteenth ceturies.

In chemistry Newton conducted a vast array of experiments, but the experimental tradition coming out of his Opticks, and not his experiments in chemistry, lay behind Lavoisier calling himself a Newtonian; indeed, one must wonder whether

Lavoisier would even have associated his new form of chemistry with Newton had he been aware of Newton's fascination with writings in the alchemical tradition.

And even in theology, there is Newton the anti-Trinitarian mild heretic who was not that much more radical in his departures from Roman and Anglican Christianity than many others at the time, and Newton, the wild religious zealot predicting the end of the Earth, who did not emerge to public view until quite recently.

There is surprisingly little cross-referencing of themes from one area of Newton's endeavors to another. The common element across almost all of them is that of a problem-solver extraordinaire, taking on one problem at a time and staying with it until he had found, usually rather promptly, a solution.

All of his technical writings display this, but so too does his unpublished manuscript reconstructing Solomon's Temple from the biblical account of it and his posthumously published Chronology of the Ancient Kingdoms in which he attempted to infer from astronomical phenomena the dating of major events in the Old Testament.

The Newton one encounters in his writings seems to compartmentalize his interests at any given moment. Whether he had a unified conception of what he was up to in all his intellectual efforts, and if so what this conception might be, has been a continuing source of controversy among Newton scholars.

Of course, were it not for the Principia, there would be no entry at all for Newton in an Encyclopedia of Philosophy.

In science, he would have been known only for the contributions he made to optics, which, while notable, were no more so than those made by Huygens and Grimaldi, neither of whom had much impact on philosophy; and in mathematics, his failure to publish would have relegated his work to not much more than a footnote to the achievements of Leibniz and his school.

Regardless of which aspect of Newton's endeavors "Newtonian" might be applied to, the word gained its aura from the Principia. But this adds still a further complication, for the Principia itself was substantially different things to different people.

The press-run of the first edition (estimated to be around 300) was too small for it to have been read by all that many individuals.

The second edition also appeared in two pirated Amsterdam editions, and hence was much more widely available, as was the third edition and its English (and later French) translation.

The Principia, however, is not an easy book to read, so one must still ask, even of those who had access to it, whether they read all or only portions of the book and to what extent they grasped the full complexity of what they read.

The detailed commentary provided in the three volume Jesuit edition (1739–42) made the work less daunting.

But even then the vast majority of those invoking the word "Newtonian" were unlikely to have been much more conversant with the Principia itself than those in the first half of the 20th

century who invoked ‘relativity’ were likely to have read Einstein's two special relativity papers of 1905 or his general relativity paper of 1916.

An important question to ask of any philosophers commenting on Newton is, what primary sources had they read?

The 1740s witnessed a major transformation in the standing of the science in the Principia. The Principia itself had left a number of loose-ends, most of them detectable by only highly discerning readers.

By 1730, however, some of these loose-ends had been cited in Bernard le Bovier de Fontenelle's elogium for Newton[4] and in John Machin's appendix to the 1729 English translation of the Principia, raising questions about just how secure Newton's theory of gravity was, empirically.

The shift on the continent began in the 1730s when Maupertuis convinced the Royal Academy to conduct expeditions to Lapland and Peru to determine whether Newton's claims about the non-spherical shape of the Earth and the variation of surface gravity with latitude are correct.

Several of the loose-ends were successfully resolved during the 1740's through such notable advances beyond the Principia as Clairaut's Théorie de la Figure de la Terre; the return of the expedition from Peru; d'Alembert's 1749 rigid-body solution for the wobble of the Earth that produces the precession of the equinoxes; Clairaut's 1749 resolution of the factor of 2 discrepancy between theory and observation in the mean motion of the lunar apogee, glossed over by Newton but emphasized by Machin; and the prize-winning first ever

successful description of the motion of the Moon by Tobias Mayer in 1753, based on a theory of this motion derived from gravity by Euler in the early 1750s taking advantage of Clairaut's solution for the mean motion of the apogee.

Euler was the central figure in turning the three laws of motion put forward by Newton in the Principia into Newtonian mechanics.

These three laws, as Newton formulated them, apply to “point-masses,” a term Euler had put forward in his Mechanica of 1736. Most of the effort of eighteenth century mechanics was devoted to solving problems of the motion of rigid bodies, elastic strings and bodies, and fluids, all of which require principles beyond Newton's three laws.

From the 1740s on this led to alternative approaches to formulating a general mechanics, employing such different principles as the conservation of vis viva, the principle of least action, and d'Alembert's principle.

The “Newtonian” formulation of a general mechanics sprang from Euler's proposal in 1750 that Newton's second law, in an F=ma formulation that appears nowhere in the Principia, could be applied locally within bodies and fluids to yield differential equations for the motions of bodies, elastic and rigid, and fluids.

During the 1750s Euler developed his equations for the motion of fluids, and in the 1760s, his equations of rigid-body motion. What we call Newtonian mechanics was accordingly something for which Euler was more responsible than Newton.

Although some loose-ends continued to defy resolution until much later in the eighteenth century, by the early 1750s Newton's theory of gravity had become the accepted basis for ongoing research among almost everyone working in orbital astronomy.

Clairaut's successful prediction of the month of return of Halley's comet at the end of this decade made a larger segment of the educated public aware of the extent to which empirical grounds for doubting Newton's theory of gravity had largely disappeared.

Even so, one must still ask of anyone outside active research in gravitational astronomy just how aware they were of the developments from ongoing efforts when they made their various pronouncements about the standing of the science of the Principia among the community of researchers.

The naivety of these pronouncements cuts both ways: on the one hand, they often reflected a bloated view of how secure Newton's theory was at the time, and, on the other, they often underestimated how strong the evidence favoring it had become.

The upshot is a need to be attentive to the question of what anyone, even including Newton himself, had in mind when they spoke of the science of the Principia.

To view the seventy years of research after Newton died as merely tying up the loose-ends of the Principia or as simply compiling more evidence for his theory of gravity is to miss the whole point.

Research predicated on Newton's theory had answered a huge number of questions about the world dating from long before it. The motion of the Moon and the trajectories of comets were two early examples, both of which answered such questions as how one comet differs from another and what details make the Moon's motion so much more complicated than that of the satellites of Jupiter and Saturn.

In the 1770s Laplace had developed a proper theory of the tides, reaching far beyond the suggestions Newton had made in the Principia by including the effects of the Earth's rotation and the non-radial components of the gravitational forces of the Sun and Moon, components that dominate the radial component that Newton had singled out.

In 1786 Laplace identified a large 900-year fluctuation in the motions of Jupiter and Saturn arising from quite subtle features of their respective orbits. With this discovery, calculation of the motion of the planets from the theory of gravity became the basis for predicting planet positions, with observation serving primarily to identify further forces not yet taken into consideration in the calculation.

These advances in our understanding of planetary motion led Laplace to produce the four principal volumes of his Traité de mécanique céleste from 1799 to 1805, a work collecting in one place all the theoretical and empirical results of the research predicated on Newton's Principia. From that time forward, Newtonian science sprang from Laplace's work, not Newton's.

The success of the research in celestial mechanics predicated on the Principia was unprecedented.

Nothing of comparable scope and accuracy had ever occurred before in empirical research of any kind. That led to a new philosophical question: what was it about the science of the Principia that enabled it to achieve what it did?

Philosophers like Locke and Berkeley began asking this question while Newton was still alive, but it gained increasing force as successes piled on one another over the decades after he died.

This question had a practical side, as those working in other fields like chemistry pursued comparable success, and others like Hume and Adam Smith aimed for a science of human affairs.

It had, of course, a philosophical side, giving rise to the subdiscipline of philosophy of science, starting with Kant and continuing throughout the nineteenth century as other areas of physical science began showing similar signs of success.

The Einsteinian revolution in the beginning of the twentieth century, in which Newtonian theory was shown to hold only as a limiting case of the special and general theories of relativity, added a further twist to the question, for now all the successes of Newtonian science, which still remain in place, have to be seen as predicated on a theory that holds only to high approximation in parochial circumstances.

The extraordinary character of the Principia gave rise to a still continuing tendency to place great weight on everything Newton said. This, however, was, and still is, easy to carry to excess.

One need look no further than Book 2 of the Principia to see that Newton had no more claim to being somehow in tune with nature and the truth than any number of his contemporaries.

Newton's manuscripts do reveal an exceptional level of attention to detail of phrasing, from which we can rightly conclude that his pronouncements, especially in print, were generally backed by careful, self-critical reflection. But this conclusion does not automatically extend to every statement he ever made.

We must constantly be mindful of the possibility of too much weight being placed, then or now, on any pronouncement that stands in relative isolation over his 60-year career; and, to counter the tendency to excess, we should be even more vigilant than usual in not losing sight of the context, circumstantial as well as historical and textual, of both Newton's statements and the eighteenth century reaction to them.

About Dr. Edmund Halley

Edmond Halley, Edmond also spelled Edmund, (born Nov. 8, 1656, Haggerston, Shoreditch, near London—died Jan.

14, 1742, Greenwich, near London), English astronomer and mathematician who was the first to calculate the orbit of a comet later named after him.

He is also noted for his role in the publication of Isaac Newton's Philosophiae Naturalism Principia Mathematica.

Early life

Halley began his education at St. Paul's School, London. He had the good fortune to live through a period of scientific revolution that established the basis of modern thought.

He was four years old when the monarchy was restored under Charles II; two years later the new monarch granted a charter to the informal organization of natural philosophers originally called the "invisible college," which then became known officially as the Royal Society of London.

Halley entered Queen's College, Oxford, in 1673 and there was introduced, by letter, to John Flamsteed, who was appointed astronomer royal in 1676. On one or two occasions Halley visited the Royal Greenwich Observatory, where Flamsteed did his work, and there was encouraged to study astronomy.

Influenced by Flamsteed's project of using the telescope to compile an accurate catalog of northern stars, Halley proposed to do the same for the Southern Hemisphere. With financial assistance from his father and, from King Charles II, an introduction to the East India Company, he sailed in November 1676 in a ship of that company (having left Oxford without his degree) for the island of St.

Helena, the southernmost territory under British rule, in the South Atlantic. Bad weather frustrated his full expectations. But, when he embarked for home in January 1678, he had recorded the celestial longitudes and latitudes of 341 stars, observed a transit of Mercury across the Sun's disk, made numerous pendulum observations, and noticed that some stars apparently had become fainter since their observation in antiquity.

alley's star catalog, published late in 1678, was the first such work to be published containing telescopically determined locations of southern stars, and it established his reputation as an astronomer.

In 1678 he was elected a fellow of the Royal Society and, with the intercession of the king, was granted the M.A. degree from the University of Oxford.

Halley and Newton

In 1684 Halley made his first visit to Isaac Newton in Cambridge, an event that led to his prominent role in the development of the theory of gravitation. Halley was the youngest of a trio of Royal Society members in London that included Robert Hooke, the inventor and microscopist, and Sir Christopher Wren, the famous architect, both of whom, with Newton at Cambridge, were attempting to find a mechanical explanation for planetary motion.

Their problem was to determine what forces would keep a planet in forward motion around the Sun without either flying off into space or falling into the Sun. Since these men were dependent upon their scientific stature for both livelihood and sense of achievement, each had a personal interest in being the first to find a solution.

This desire for priority, a propelling motive in science, was the cause of much lively discussion and competition between them.

Although Hooke and Halley had reasoned that the force keeping a planet in orbit must decrease as the inverse of the square of its distance from the Sun, they were not able to deduce from

this hypothesis a theoretical orbit that would match the observed planetary motions, despite the incentive of a prize offered by Wren.

Halley then visited Newton, who told him he had already solved the problem—the orbit would be an ellipse—but that he had mislaid his calculations to prove it.

Encouraged by Halley, Newton then expanded his studies on celestial mechanics into one of the greatest masterpieces produced by the mind of man, the Principia.

The Royal Society decided that “Mr. Halley undertake the business of looking after it, and printing it at his own charge,” which he proceeded to do. He consulted with Newton, tactfully subdued a priority dispute between Newton and Hooke, edited the text of the Principia, wrote laudatory verse in Latin for the preface to honour its author, corrected the proofs, and saw it through the press in 1687.

Later works

Halley had the ability to reduce large amounts of data to a meaningful order. In 1686 his map of the world, showing the distribution of prevailing winds over the oceans, was the first meteorological chart to be published.

His mortality tables for the city of Breslau, Ger. (now Wrocław, Pol.), published in 1693, comprised one of the first attempts to relate mortality and age in a population; as such, it influenced the future development of actuarial tables in life insurance.

Under instructions from the Admiralty, he commanded the war sloop Paramore Pink in 1698–1700 on one of the first sea

voyages undertaken for purely scientific purposes, this one to make measurements of the compass declination in the South Atlantic and to determine accurate latitudes and longitudes of his ports of call.

(The declination is the angle between magnetic north and true north.) In 1701 he published the first magnetic charts of the Atlantic Ocean and some of the Pacific Ocean, showing curved lines that indicated positions in the oceans having the same compass declination.

These charts, compiled from all available observations and augmented by his own, were intended to be useful for navigation and perhaps to solve the great problem of determining the longitude at sea.

However, because it was difficult to determine the compass declination with sufficient accuracy and because it was soon discovered that compass declination can vary from year to year, this method of finding longitude was never widely adopted. Notwithstanding opposition from Flamsteed, Halley in 1704 was appointed Savilian professor of geometry at Oxford.

Continuing his pioneering work in observational astronomy, Halley published in 1705 A Synopsis of the Astronomy of Comets, in which he described the parabolic orbits of 24 comets that had been observed from 1337 to 1698.

He showed that the three historic comets of 1531, 1607, and 1682 were so similar in characteristics that they must have been successive returns of the same visitant—now known as Halley's Comet—and accurately predicted its return in 1758.

In 1716 he devised a method for observing transits of Venus across the disk of the Sun, predicted for 1761 and 1769, in order to determine accurately, by solar parallax, the distance of Earth from the Sun.

In 1718, by comparing recently observed star positions with data recorded in the ancient Greek astronomer Ptolemy's Almagest, he found that Sirius and Arcturus had slightly shifted their positions with respect to their neighbours.

This was the discovery of what modern astronomers call proper motion.

(Halley incorrectly announced proper motions for two other stars, Aldebaran and Betelgeuse, but for these was misled by errors in the ancient star positions).

In 1720 Halley succeeded Flamsteed as astronomer royal at Greenwich, where he made observations, such as timing the transits of the Moon across the meridian, that he hoped would eventually be useful in determining longitude at sea.

Halley's significance

Halley's concern with practical applications of science, such as problems of navigation, reflects the influence on the Royal Society of British author Francis Bacon, who held that science should be for the "relief of man's estate." Though wide-ranging in his interests, Halley displayed a high degree of professional competence that foreshadowed scientific specialization.

His wise assessment of Newton's work and his persistence in guiding it to completion earned for him an important place in the emergence of Western thought

About Michael Faraday

Early life

Michael Faraday was born on 22 September 1791 in Newington Butts, Surrey (which is now part of the London Borough of Southwark).

His family was not well off. His father, James, was a member of the Glasite sect of Christianity. James Faraday moved his wife, Margaret (née Hastwell), and two children to London during the winter of 1790 from Outhgill in Westmorland, where he had been an apprentice to the village blacksmith. Michael was born in the autumn of that year.

The young Michael Faraday, who was the third of four children, having only the most basic school education, had to educate himself.

At the age of 14 he became an apprentice to George Riebau, a local bookbinder and bookseller in Blandford Street. During his seven-year apprenticeship Faraday read many books, including Isaac Watts's The Improvement of the Mind, and he enthusiastically implemented the principles and suggestions contained therein.

During this period, Faraday held discussions with his peers in the City Philosophical Society where he attended lectures about various scientific topics.

He also developed an interest in science, especially in electricity. Faraday was particularly inspired by the book Conversations on Chemistry by Jane Marcet.

In 1812, at the age of 20 and at the end of his apprenticeship, Faraday attended lectures by the eminent English chemist Humphry Davy of the Royal Institution and the Royal Society, and John Tatum, founder of the City Philosophical Society.

Many of the tickets for these lectures were given to Faraday by William Dance, who was one of the founders of the Royal Philharmonic Society. Faraday subsequently sent Davy a 300-page book based on notes that he had taken during these lectures.

Davy's reply was immediate, kind, and favourable. In 1813, when Davy damaged his eyesight in an accident with nitrogen trichloride, he decided to employ Faraday as an assistant. Coincidentally one of the Royal Institution's assistants, John Payne, was sacked and Sir Humphry Davy had been asked to find a replacement; thus he appointed Faraday as Chemical Assistant at the Royal Institution on 1 March 1813.

Very soon Davy entrusted Faraday with the preparation of nitrogen trichloride samples, and they both were injured in an explosion of this very sensitive substance.

Faraday married Sarah Barnard (1800–1879) on 12 June 1821. They met through their families at the Sandemanian church, and he confessed his faith to the Sandemanian congregation the month after they were married. They had no children.

Faraday was a devout Christian; his Sandemanian denomination was an offshoot of the Church of Scotland. Well after his marriage, he served as deacon and for two terms as an elder in the meeting house of his youth. His church was located at Paul's Alley in the Barbican.

This meeting house relocated in 1862 to Barnsbury Grove, Islington; this North London location was where Faraday served the final two years of his second term as elder prior to his resignation from that post.

Biographers have noted that "a strong sense of the unity of God and nature pervaded Faraday's life and work."

Later life

Three Fellows of the Royal Society offering the presidency to Faraday, 1857

In June 1832, the University of Oxford granted Faraday an honorary Doctor of Civil Law degree. During his lifetime, he was offered a knighthood in recognition for his services to science, which he turned down on religious grounds, believing that it was against the word of the Bible to accumulate riches and pursue worldly reward, and stating that he preferred to remain "plain Mr Faraday to the end".

Elected a Fellow of the Royal Society in 1824, he twice refused to become President. He became the first Fullerian Professor of Chemistry at the Royal Institution in 1833.

In 1832, Faraday was elected a Foreign Honorary Member of the American Academy of Arts and Sciences. He was elected a foreign member of the Royal Swedish Academy of Sciences in 1838. In 1840, he was elected to the American Philosophical Society. He was one of eight foreign members elected to the French Academy of Sciences in 1844.

In 1849 he was elected as associated member to the Royal Institute of the Netherlands, which two years later became the

Royal Netherlands Academy of Arts and Sciences and he was subsequently made foreign member.

Faraday's grave at Highgate Cemetery, London

Faraday suffered a nervous breakdown in 1839 but eventually returned to his investigations into electromagnetism.

In 1848, as a result of representations by the Prince Consort, Faraday was awarded a grace and favour house in Hampton Court in Middlesex, free of all expenses and upkeep. This was the Master Mason's House, later called Faraday House, and now No. 37 Hampton Court Road.

In 1858 Faraday retired to live there.

Having provided a number of various service projects for the British government, when asked by the government to advise on the production of chemical weapons for use in the Crimean War (1853–1856), Faraday refused to participate, citing ethical reasons.

Faraday died at his house at Hampton Court on 25 August 1867, aged 75. He had some years before turned down an offer of burial in Westminster Abbey upon his death, but he has a memorial plaque there, near Isaac Newton's tomb. Faraday was interred in the dissenters' (non-Anglican) section of Highgate Cemetery.

Scientific achievements

Chemistry

Equipment used by Faraday to make glass on display at the Royal Institution in London

Faraday's earliest chemical work was as an assistant to Humphry Davy.

Faraday was involved in the study of chlorine; he discovered two new compounds of chlorine and carbon.

He also conducted the first rough experiments on the diffusion of gases, a phenomenon that was first pointed out by John Dalton. The physical importance of this phenomenon was more fully revealed by Thomas Graham and Joseph Loschmidt. Faraday succeeded in liquefying several gases, investigated the alloys of steel, and produced several new kinds of glass intended for optical purposes.

A specimen of one of these heavy glasses subsequently became historically important; when the glass was placed in a magnetic field Faraday determined the rotation of the plane of polarisation of light. This specimen was also the first substance found to be repelled by the poles of a magnet.

Faraday invented an early form of what was to become the Bunsen burner, which is still in practical use in science laboratories around the world as a convenient source of heat.

Faraday worked extensively in the field of chemistry, discovering chemical substances such as benzene (which he called bicarburet of hydrogen) and liquefying gases such as chlorine.

The liquefying of gases helped to establish that gases are the vapours of liquids possessing a very low boiling point and gave a more solid basis to the concept of molecular aggregation.

In 1820 Faraday reported the first synthesis of compounds made from carbon and chlorine, C_2Cl_6 and C_2Cl_4, and published his results the following year. Faraday also determined the composition of the chlorine clathrate hydrate, which had been discovered by Humphry Davy in 1810.

Faraday is also responsible for discovering the laws of electrolysis, and for popularizing terminology such as anode, cathode, electrode, and ion, terms proposed in large part by William Whewell.

Faraday was the first to report what later came to be called metallic nanoparticles. In 1847 he discovered that the optical properties of gold colloids differed from those of the corresponding bulk metal.

This was probably the first reported observation of the effects of quantum size, and might be considered to be the birth of nanoscience.

Electricity and magnetism

Faraday is best known for his work on electricity and magnetism. His first recorded experiment was the construction of a voltaic pile with seven British halfpenny coins, stacked together with seven discs of sheet zinc, and six pieces of paper moistened with salt water.

With this pile he decomposed sulfate of magnesia (first letter to Abbott, 12 July 1812).

Electromagnetic rotation experiment of Faraday, 1821, the first demonstration of the conversion of electrical energy into motion

In 1821, soon after the Danish physicist and chemist Hans Christian Ørsted discovered the phenomenon of electromagnetism, Davy and William Hyde Wollaston tried, but failed, to design an electric motor.

Faraday, having discussed the problem with the two men, went on to build two devices to produce what he called "electromagnetic rotation". One of these, now known as the homopolar motor, caused a continuous circular motion that was engendered by the circular magnetic force around a wire that extended into a pool of mercury wherein was placed a magnet; the wire would then rotate around the magnet if supplied with current from a chemical battery.

These experiments and inventions formed the foundation of modern electromagnetic technology. In his excitement, Faraday published results without acknowledging his work with either Wollaston or Davy.

The resulting controversy within the Royal Society strained his mentor relationship with Davy and may well have contributed to Faraday's assignment to other activities, which consequently prevented his involvement in electromagnetic research for several years.

One of Faraday's 1831 experiments demonstrating induction. The liquid battery (right) sends an electric current through the small coil (A).

When it is moved in or out of the large coil (B), its magnetic field induces a momentary voltage in the coil, which is detected by the galvanometer (G).

From his initial discovery in 1821, Faraday continued his laboratory work, exploring electromagnetic properties of materials and developing requisite experience.

In 1824, Faraday briefly set up a circuit to study whether a magnetic field could regulate the flow of a current in an adjacent wire, but he found no such relationship. This experiment followed similar work conducted with light and magnets three years earlier that yielded identical results. During the next seven years, Faraday spent much of his time perfecting his recipe for optical quality (heavy) glass, borosilicate of lead, which he used in his future studies connecting light with magnetism.

In his spare time, Faraday continued publishing his experimental work on optics and electromagnetism; he conducted correspondence with scientists whom he had met on his journeys across Europe with Davy, and who were also working on electromagnetism.

Two years after the death of Davy, in 1831, he began his great series of experiments in which he discovered electromagnetic induction, recording in his laboratory diary on 28 October 1831 he was; "making many experiments with the great magnet of the Royal Society".

Faraday's breakthrough came when he wrapped two insulated coils of wire around an iron ring, and found that, upon passing a current through one coil, a momentary current was induced in the other coil. This phenomenon is now known as mutual induction. The iron ring-coil apparatus is still on display at the Royal Institution.

In subsequent experiments, he found that if he moved a magnet through a loop of wire an electric current flowed in that wire. The current also flowed if the loop was moved over a stationary magnet.

His demonstrations established that a changing magnetic field produces an electric field; this relation was modelled mathematically by James Clerk Maxwell as Faraday's law, which subsequently became one of the four Maxwell equations, and which have in turn evolved into the generalization known today as field theory.

Faraday would later use the principles he had discovered to construct the electric dynamo, the ancestor of modern power generators and the electric motor.

Faraday (right) and John Daniell (left), founders of electrochemistry

In 1832, he completed a series of experiments aimed at investigating the fundamental nature of electricity; Faraday used "static", batteries, and "animal electricity" to produce the phenomena of electrostatic attraction, electrolysis, magnetism, etc. He concluded that, contrary to the scientific opinion of the time, the divisions between the various "kinds" of electricity were illusory.

Faraday instead proposed that only a single "electricity" exists, and the changing values of quantity and intensity (current and voltage) would produce different groups of phenomena.

Near the end of his career, Faraday proposed that electromagnetic forces extended into the empty space around the conductor.

This idea was rejected by his fellow scientists, and Faraday did not live to see the eventual acceptance of his proposition by the scientific community.

Faraday's concept of lines of flux emanating from charged bodies and magnets provided a way to visualize electric and magnetic fields; that conceptual model was crucial for the successful development of the electromechanical devices that dominated engineering and industry for the remainder of the 19th century.

Diamagnetism

Faraday holding a type of glass bar he used in 1845 to show magnetism affects light in dielectric material

In 1845, Faraday discovered that many materials exhibit a weak repulsion from a magnetic field: a phenomenon he termed diamagnetism.

Faraday also discovered that the plane of polarization of linearly polarized light can be rotated by the application of an external magnetic field aligned with the direction in which the light is moving.

This is now termed the Faraday effect.

In Sept 1845 he wrote in his notebook, "I have at last succeeded in illuminating a magnetic curve or line of force and in magnetising a ray of light".

Later on in his life, in 1862, Faraday used a spectroscope to search for a different alteration of light, the change of spectral lines by an applied magnetic field.

The equipment available to him was, however, insufficient for a definite determination of spectral change. Pieter Zeeman later used an improved apparatus to study the same phenomenon, publishing his results in 1897 and receiving the 1902 Nobel Prize in Physics for his success.

In both his 1897 paper and his Nobel acceptance speech, Zeeman made reference to Faraday's work.

Faraday holding a type of glass bar he used in 1845 to show magnetism affects light in dielectric material. In 1845, Faraday discovered that many materials exhibit a weak repulsion from a magnetic field: a phenomenon he termed diamagnetism.

Faraday also discovered that the plane of polarization of linearly polarized light can be rotated by the application of an external magnetic field aligned with the direction in which the light is moving.

This is now termed the Faraday effect. In Sept 1845 he wrote in his notebook, "I have at last succeeded in illuminating a magnetic curve or line of force and in magnetizing a ray of light".

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Faraday cage

In his work on static electricity, Faraday's ice pail experiment demonstrated that the charge resided only on the exterior of a charged conductor, and exterior charge had no influence on anything enclosed within a conductor.

This is because the exterior charges redistribute such that the interior fields emanating from them cancel one another. This shielding effect is used in what is now known as a Faraday cage. In January 1836, Faraday had put a wooden frame, 12ft square, on four glass supports and added paper walls and wire mesh. He then stepped inside and electrified it.

When he stepped out of his electrified cage, Faraday had shown that electricity was a force, not an imponderable fluid as was believed at the time.

Royal Institution and public service

Michael Faraday meets Father Thames, from Punch (21 July 1855)

Faraday had a long association with the Royal Institution of Great Britain. He was appointed Assistant Superintendent of the House of the Royal Institution in 1821. He was elected a Fellow of the Royal Society in 1824.

In 1825, he became Director of the Laboratory of the Royal Institution. Six years later, in 1833, Faraday became the first Fullerian Professor of Chemistry at the Royal Institution of Great Britain, a position to which he was appointed for life without the obligation to deliver lectures.

His sponsor and mentor was John 'Mad Jack' Fuller, who created the position at the Royal Institution for Faraday.

Beyond his scientific research into areas such as chemistry, electricity, and magnetism at the Royal Institution, Faraday undertook numerous, and often time-consuming, service projects for private enterprise and the British government.

This work included investigations of explosions in coal mines, being an expert witness in court, and along with two engineers from Chance Brothers c.1853, the preparation of high-quality optical glass, which was required by Chance for its lighthouses. In 1846, together with Charles Lyell, he produced a lengthy and detailed report on a serious explosion in the colliery at Haswell, County Durham, which killed 95 miners.

Their report was a meticulous forensic investigation and indicated that coal dust contributed to the severity of the explosion.

The first-time explosions had been linked to dust, Faraday gave a demonstration during a lecture on how ventilation could prevent it. The report should have warned coal owners of the hazard of coal dust explosions, but the risk was ignored for over 60 years until the 1913 Senghenydd Colliery Disaster.

As a respected scientist in a nation with strong maritime interests, Faraday spent extensive amounts of time on projects such as the construction and operation of lighthouses and protecting the bottoms of ships from corrosion.

His workshop still stands at Trinity Buoy Wharf above the Chain and Buoy Store, next to London's only lighthouse where he carried out the first experiments in electric lighting for lighthouses.

Faraday was also active in what would now be called environmental science, or engineering. He investigated industrial pollution at Swansea and was consulted on air pollution at the Royal Mint. In July 1855, Faraday wrote a letter to The Times on the subject of the foul condition of the River Thames, which resulted in an often-reprinted cartoon in Punch.

Faraday's apparatus for experimental demonstration of ideomotor effect on table-turning

Faraday assisted with the planning and judging of exhibits for the Great Exhibition of 1851 in London. He also advised the National Gallery on the cleaning and protection of its art collection, and served on the National Gallery Site Commission in 1857. Education was another of Faraday's areas of service; he lectured on the topic in 1854 at the Royal Institution, and, in 1862, he appeared before a Public Schools Commission to give his views on education in Great Britain.

Faraday also weighed in negatively on the public's fascination with table-turning, mesmerism, and seances, and in so doing chastised both the public and the nation's educational system.

Faraday delivering a Christmas Lecture at the Royal Institution in 1856, Before his famous Christmas lectures, Faraday delivered chemistry lectures for the City Philosophical Society from 1816 to 1818 in order to refine the quality of his lectures.

Between 1827 and 1860 at the Royal Institution in London, Faraday gave a series of nineteen Christmas lectures for young people, a series which continues today.

The objective of the lectures was to present science to the general public in the hopes of inspiring them and generating revenue for the Royal Institution. They were notable events on the social calendar among London's gentry.

Over the course of several letters to his close friend Benjamin Abbott, Faraday outlined his recommendations on the art of lecturing, writing "a flame should be lighted at the commencement and kept alive with unremitting splendour to the end".

His lectures were joyful and juvenile, he delighted in filling soap bubbles with various gasses (in order to determine whether or not they are magnetic), but the lectures were also deeply philosophical. In his lectures he urged his audiences to consider the mechanics of his experiments: "you know very well that ice floats upon water ...

Why does the ice float?

Think of that, and philosophise".

The subjects in his lectures consisted of Chemistry and Electricity, and included: 1841: The Rudiments of Chemistry, 1843: First Principles of Electricity, 1848: The Chemical History

of a Candle, 1851: Attractive Forces, 1853: Voltaic Electricity, 1854: The Chemistry of Combustion, 1855: The Distinctive Properties of the Common Metals, 1857: Static Electricity, 1858: The Metallic Properties, 1859: The Various Forces of Matter and their Relations to Each Other.

Commemorations

A statue of Faraday stands in Savoy Place, London, outside the Institution of Engineering and Technology.

The Michael Faraday Memorial, designed by brutalist architect Rodney Gordon and completed in 1961, is at the Elephant & Castle gyratory system, near Faraday's birthplace at Newington Butts, London.

Faraday School is located on Trinity Buoy Wharf where his workshop still stands above the Chain and Buoy Store, next to London's only lighthouse.

Faraday Gardens is a small park in Walworth, London, not far from his birthplace at Newington Butts. It lies within the local council ward of Faraday in the London Borough of Southwark.

Michael Faraday Primary school is situated on the Aylesbury Estate in Walworth.

A building at London South Bank University, which houses the institute's electrical engineering departments is named the Faraday Wing, due to its proximity to Faraday's birthplace in Newington Butts.

A hall at Loughborough University was named after Faraday in 1960.

Near the entrance to its dining hall is a bronze casting, which depicts the symbol of an electrical transformer, and inside there hangs a portrait, both in Faraday's honour.

An eight-story building at the University of Edinburgh's science & engineering campus is named for Faraday, as is a recently built hall of accommodation at Brunel University, the main engineering building at Swansea University, and the instructional and experimental physics building at Northern Illinois University. The former UK Faraday Station in Antarctica was named after him.

Without such freedom there would have been no Shakespeare, no Goethe, no Newton, no Faraday, no Pasteur and no Lister.

Streets named for Faraday can be found in many British cities (e.g., London, Fife, Swindon, Basingstoke, Nottingham, Whitby, Kirkby, Crawley, Newbury, Swansea, Aylesbury and Stevenage) as well as in France (Paris), Germany (Berlin-Dahlem, Hermsdorf), Canada (Quebec City, Quebec; Deep River, Ontario; Ottawa, Ontario), the United States (Reston, Virginia), and New Zealand (Hawke's Bay).

A Royal Society of Arts blue plaque, unveiled in 1876, commemorates Faraday at 48 Blandford Street in London's Marylebone district. From 1991 until 2001, Faraday's picture featured on the reverse of Series E £20 banknotes issued by the Bank of England.

He was portrayed conducting a lecture at the Royal Institution with the magneto-electric spark apparatus. In 2002, Faraday was ranked number 22 in the BBC's list of the 100 Greatest Britons following a UK-wide vote.

Faraday has been commemorated on postage stamps issued by the Royal Mail. In 1991, as a pioneer of electricity he featured in their Scientific Achievements issue along with pioneers in three other fields (Charles Babbage (computing), Frank Whittle (jet engine) and Robert Watson-Watt (radar)). In 1999, under the title "Faraday's Electricity", he featured in their World Changers issue along with Charles Darwin, Edward Jenner and Alan Turing.

The Faraday Institute for Science and Religion derives its name from the scientist, who saw his faith as integral to his scientific research. The logo of the institute is also based on Faraday's discoveries. It was created in 2006 by a $2,000,000 grant from the John Templeton Foundation to carry out academic research, to foster understanding of the interaction between science and religion, and to engage public understanding in both these subject areas.

The Faraday Institution, an independent energy storage research institute established in 2017, also derives its name from Michael Faraday. The organization serves as the UK's primary research programmed to advance battery science and technology, education, public engagement and market research.

Faraday's life and contributions to electromagnetics was the principal topic of the tenth episode, titled "The Electric Boy", of the 2014 American science documentary series, Cosmos: A Space-time Odyssey, which was broadcast on Fox and the National Geographic Channel.

Aldous Huxley wrote about Faraday in an essay entitled, A Night in Pietramala: "He is always the natural philosopher. To discover truth is his sole aim and interest ... even if I could be Shakespeare, I think I should still choose to be Faraday.

Calling Faraday, her "hero", in a speech to the Royal Society, Margaret Thatcher declared: "The value of his work must be higher than the capitalization of all the shares on the Stock Exchange!" She borrowed his bust from the Royal Institution and had it placed in the hall of 10 Downing Street.

About Albert Einstein

Albert Einstein (/ˈaɪnstaɪn/ EYEN-styne;[4] German: ; 14 March 1879 – 18 April 1955) was a German-born theoretical physicist, widely acknowledged to be one of the greatest and most influential physicists of all time.

Best known for developing the theory of relativity, he also made important contributions to the development of the theory of quantum mechanics. Relativity and quantum mechanics are the two pillars of modern physics.

His mass–energy equivalence formula E = mc2, which arises from relativity theory, has been dubbed "the world's most famous equation". His work is also known for its influence on the philosophy of science.

He received the 1921 Nobel Prize in Physics "for his services to theoretical physics, and especially for his discovery of the law of the photoelectric effect", a pivotal step in the development of quantum theory.

His intellectual achievements and originality resulted in "Einstein" becoming synonymous with "genius". Einsteinium, one of the synthetic elements in the periodic table, was named in his honor.

In 1905, a year sometimes described as his annus mirabilis ('miracle year'), Einstein published four groundbreaking papers. These outlined the theory of the photoelectric effect, explained Brownian motion, introduced special relativity, and demonstrated mass–energy equivalence.

He thought that the laws of classical mechanics could no longer be reconciled with those of the electromagnetic field, which led him to develop his special theory of relativity. He then extended the theory to gravitational fields; he published a paper on general relativity in 1916, introducing his theory of gravitation. In 1917, he applied the general theory of relativity to model the structure of the universe.

He continued to deal with problems of statistical mechanics and quantum theory, which led to his explanations of particle theory and the motion of molecules. He also investigated the thermal properties of light and the quantum theory of radiation, which laid the foundation of the photon theory of light.

However, for much of the later part of his career, he worked on two ultimately unsuccessful endeavors. First, despite his great contributions to quantum mechanics, he opposed what it evolved into, objecting that "God does not play dice". Second, he attempted to devise a unified field theory by generalizing his geometric theory of gravitation to include electromagnetism.

As a result, he became increasingly isolated from the mainstream of modern physics.

Einstein was born in the German Empire, but moved to Switzerland in 1895, forsaking his German citizenship (as a subject of the Kingdom of Württemberg) the following year.

In 1897, at the age of 17, he enrolled in the mathematics and physics teaching diploma program at the Swiss Federal polytechnic school in Zürich, graduating in 1900. In 1901, he acquired Swiss citizenship, which he kept for the rest of his life, and in 1903, he secured a permanent position at the Swiss Patent Office in Bern.

In 1905, he was awarded a PhD by the University of Zurich. In 1914, he moved to Berlin in order to join the Prussian Academy of Sciences and the Humboldt University of Berlin. In 1917, he became director of the Kaiser Wilhelm Institute for Physics; he also became a German citizen again, this time Prussian.

In 1933, while he was visiting the United States, Adolf Hitler came to power in Germany. Einstein objected to the policies of the newly elected Nazi government; he settled in the United States and became an American citizen in 1940.

On the eve of World War II, he endorsed a letter to President Franklin D. Roosevelt alerting him to the potential German nuclear weapons program and recommending that the US begin similar research.

Einstein supported the Allies but generally denounced the idea of nuclear weapons.

Life and career

Early life and education

A young boy with short hair and a round face, wearing a white collar and large bow, with vest, coat, skirt, and high boots. He is leaning against an ornate chair.

Albert Einstein was born in Ulm, in the Kingdom of Württemberg in the German Empire, on 14 March 1879 into a family of secular Ashkenazi Jews. His parents were Hermann Einstein, a salesman and engineer, and Pauline Koch.

In 1880, the family moved to Munich, where Einstein's father and his uncle Jakob founded Elektrotechnische Fabrik J. Einstein & Cie, a company that manufactured electrical equipment based on direct current.

Albert attended a Catholic elementary school in Munich, from the age of five, for three years. At the age of eight, he was transferred to the Luitpold-Gymnasium (now known as the Albert-Einstein-Gymnasium), where he received advanced primary and secondary school education until he left the German Empire seven years later.

In 1894, Hermann and Jakob's company lost a bid to supply the city of Munich with electrical lighting because they lacked the capital to convert their equipment from the direct current (DC) standard to the more efficient alternating current (AC) standard. The loss forced the sale of the Munich factory.

In search of business, the Einstein family moved to Italy, first to Milan and a few months later to Pavia. In Pavia, the Einsteins settled in Palazzo Cornazzani, a medieval building where, at

different times, Ugo Foscolo, Contardo Ferrini and Ada Negri lived.

When the family moved to Pavia, Einstein, then 15, stayed in Munich to finish his studies at the Luitpold Gymnasium. His father intended for him to pursue electrical engineering, but Einstein clashed with the authorities and resented the school's regimen and teaching method.

He later wrote that the spirit of learning and creative thought was lost in strict rote learning. At the end of December 1894, he traveled to Italy to join his family in Pavia, convincing the school to let him go by using a doctor's note.

During his time in Italy, he wrote a short essay with the title "On the Investigation of the State of the Ether in a Magnetic Field".

Einstein excelled at math and physics from a young age, reaching a mathematical level year ahead of his peers.

The 12-year-old Einstein taught himself algebra and Euclidean geometry over a single summer. Einstein also independently discovered his own original proof of the Pythagorean theorem aged 12. A family tutor Max Talmud says that only a short time after he had given the 12-year-old Einstein a geometry textbook, "[Einstein] had worked through the whole book. He thereupon devoted himself to higher mathematics ...

Soon the flight of his mathematical genius was so high I could not follow." His passion for geometry and algebra led the 12-year-old to become convinced that nature could be understood as a "mathematical structure".

Einstein started teaching himself calculus at 12, and as a 14-year-old he says he had "mastered integral and differential calculus".

At the age of 13, when he had become more seriously interested in philosophy (and music), Einstein was introduced to Kant's Critique of Pure Reason. Kant became his favorite philosopher, his tutor stating: "At the time he was still a child, only thirteen years old, yet Kant's works, incomprehensible to ordinary mortals, seemed to be clear to him."

In 1895, at the age of 16, Einstein took the entrance examinations for the Swiss Federal polytechnic school in Zürich (later the Eidgenössische Technische Hochschule, ETH). He failed to reach the required standard in the general part of the examination, but obtained exceptional grades in physics and mathematics.

On the advice of the principal of the polytechnic school, he attended the Argovian cantonal school (gymnasium) in Aarau, Switzerland, in 1895 and 1896 to complete his secondary schooling. While lodging with the family of Jost Winteler, he fell in love with Winteler's daughter, Marie.

Einstein's sister Maja later married Winteler's son Paul. In January 1896, with his father's approval, Einstein renounced his citizenship in the German Kingdom of Württemberg to avoid military service. In September 1896, he passed the Swiss Matura with mostly good grades, including a top grade of 6 in physics and mathematical subjects, on a scale of 1–6. At 17, he enrolled in the four-year mathematics and physics teaching diploma program at the Federal polytechnic school.

Marie Winteler, who was a year older, moved to Olsberg, Switzerland, for a teaching post.

Einstein's future wife, a 20-year-old Serbian named Mileva Marić, also enrolled at the polytechnic school that year. She was the only woman among the six students in the mathematics and physics section of the teaching diploma course.

Over the next few years, Einstein's and Marić's friendship developed into a romance, and they spent countless hours debating and reading books together on extra-curricular physics in which they were both interested.

Einstein wrote in his letters to Marić that he preferred studying alongside her. In 1900, Einstein passed the exams in Maths and Physics and was awarded a Federal teaching diploma. There is eyewitness evidence and several letters over many years that indicate Marić might have collaborated with Einstein prior to his landmark 1905 papers, known as the Annus Mirabilis papers, and that they developed some of the concepts together during their studies, although some historians of physics who have studied the issue disagree that she made any substantive contributions.

Marriages and children

Albert Einstein and Mileva Marić Einstein, 1912

Early correspondence between Einstein and Marić was discovered and published in 1987 which revealed that the couple had a daughter named "Lieserl", born in early 1902 in Novi Sad where Marić was staying with her parents.

Marić returned to Switzerland without the child, whose real name and fate are unknown. The contents of Einstein's letter in September 1903 suggest that the girl was either given up for adoption or died of scarlet fever in infancy.

Einstein and Marić married in January 1903. In May 1904, their son Hans Albert Einstein was born in Bern, Switzerland.

Their son Eduard was born in Zürich in July 1910. The couple moved to Berlin in April 1914, but Marić returned to Zürich with their sons after learning that, despite their close relationship before, Einstein's chief romantic attraction was now his cousin Elsa Löwenthal; she was his first cousin maternally and second cousin paternally.

Einstein and Marić divorced on 14 February 1919, having lived apart for five years. As part of the divorce settlement, Einstein agreed to give Marić any future (in the event, 1921) Nobel Prize money.

In letters revealed in 2015, Einstein wrote to his early love Marie Winteler about his marriage and his strong feelings for her. He wrote in 1910, while his wife was pregnant with their second child: "I think of you in heartfelt love every spare minute and am so unhappy as only a man can be."

He spoke about a "misguided love" and a "missed life" regarding his love for Marie.

Einstein married Löwenthal in 1919, after having had a relationship with her since 1912. They emigrated to the United States in 1933. Elsa was diagnosed with heart and kidney problems in 1935 and died in December 1936.

In 1923, Einstein fell in love with a secretary named Betty Neumann, the niece of a close friend, Hans Mühsam. In a volume of letters released by Hebrew University of Jerusalem in 2006, Einstein described about six women, including Margarete Lebach (a blonde Austrian), Estella Katzenellenbogen (the rich owner of a florist business), Toni Mendel (a wealthy Jewish widow) and Ethel Michanowski (a Berlin socialite), with whom he spent time and from whom he received gifts while being married to Elsa.

Later, after the death of his second wife Elsa, Einstein was briefly in a relationship with Margarita Konenkova. Konenkova was a Russian spy who was married to the Russian sculptor Sergei Konenkov (who created the bronze bust of Einstein at the Institute for Advanced Study at Princeton).

Einstein's son Eduard had a breakdown at about age 20 and was diagnosed with schizophrenia. His mother cared for him and he was also committed to asylums for several periods, finally, after her death, being committed permanently to Burghölzli, the Psychiatric University Hospital in Zürich.

Patent office

Head and shoulders shot of a young, moustached man with dark, curly hair wearing a plaid suit and vest, striped shirt, and a dark tie.

Einstein in 1904 (age 25)

After graduating in 1900, Einstein spent almost two years searching for a teaching post. He acquired Swiss citizenship in February 1901, but was not conscripted for medical reasons.

With the help of Marcel Grossmann's father, he secured a job in Bern at the Swiss Patent Office, as an assistant examiner – level III.

There, he evaluated patent applications for a variety of devices including a gravel sorter and an electromechanical typewriter. In 1903, his position at the patent office became permanent, although he was passed over for promotion until he "fully mastered machine technology".

Much of his work was related to questions about transmission of electric signals and electrical-mechanical synchronization of time, two technical problems that show up conspicuously in the thought experiments that eventually led Einstein to his radical conclusions about the nature of light and the fundamental connection between space and time.

With a few friends he had met in Bern, he started a small discussion group in 1902, self-mockingly named "The Olympia Academy", which met regularly to discuss science and philosophy.

Sometimes they were joined by Marić who attentively listened but did not participate. Their readings included the works of Henri Poincaré, Ernst Mach, and David Hume, which influenced his scientific and philosophical outlook.

First scientific papers

In 1900, Einstein's paper "Folgerungen aus den Capillaritätserscheinungen" ("Conclusions from the Capillarity Phenomena") was published in the journal Annalen der Physik. On 30 April 1905 Einstein completed his dissertation, A New

Determination of Molecular Dimensions with Alfred Kleiner, serving as pro-forma advisor. His thesis was accepted in July 1905, and Einstein was awarded a PhD on 15 January 1906.

Also in 1905, which has been called Einstein's annus mirabilis (amazing year), he published four groundbreaking papers, on the photoelectric effect, Brownian motion, special relativity, and the equivalence of mass and energy, which were to bring him to the notice of the academic world, at the age of 26.

Academic career

By 1908, he was recognized as a leading scientist and was appointed lecturer at the University of Bern. The following year, after he gave a lecture on electrodynamics and the relativity principle at the University of Zurich, Alfred Kleiner recommended him to the faculty for a newly created professorship in theoretical physics. Einstein was appointed associate professor in 1909.

Einstein became a full professor at the German Charles-Ferdinand University in Prague in April 1911, accepting Austrian citizenship in the Austro-Hungarian Empire to do so.

During his Prague stay, he wrote 11 scientific works, five of them on radiation mathematics and on the quantum theory of solids.

In July 1912, he returned to his alma mater in Zürich. From 1912 until 1914, he was a professor of theoretical physics at the ETH Zurich, where he taught analytical mechanics and thermodynamics.

He also studied continuum mechanics, the molecular theory of heat, and the problem of gravitation, on which he worked with mathematician and friend Marcel Grossmann.

When the "Manifesto of the Ninety-Three" was published in October 1914—a document signed by a host of prominent German intellectuals that justified Germany's militarism and position during the First World War—Einstein was one of the few German intellectuals to rebut its contents and sign the pacifistic "Manifesto to the Europeans".

The New York Times reported confirmation of "the Einstein theory" (specifically, the bending of light by gravitation) based on 29 May 1919 eclipse observations in Príncipe (Africa) and Sobral (Brazil), after the findings were presented on 6 November 1919 to a joint meeting in London of the Royal Society and the Royal Astronomical Society.

In the spring of 1913, Einstein was enticed to move to Berlin with an offer that included membership in the Prussian Academy of Sciences, and a linked University of Berlin professorship, enabling him to concentrate exclusively on research. On 3 July 1913, he became a member of the Prussian Academy of Sciences in Berlin.

Max Planck and Walther Nernst visited him the next week in Zurich to persuade him to join the academy, additionally offering him the post of director at the Kaiser Wilhelm Institute for Physics, which was soon to be established.

Membership in the academy included paid salary and professorship without teaching duties at Humboldt University of Berlin.

He was officially elected to the academy on 24 July, and he moved to Berlin the following year. His decision to move to Berlin was also influenced by the prospect of living near his cousin Elsa, with whom he had started a romantic affair.

Einstein assumed his position with the academy, and Berlin University, after moving into his Dahlem apartment on 1 April 1914. As World War I broke out that year, the plan for Kaiser Wilhelm Institute for Physics was delayed. The institute was established on 1 October 1917, with Einstein as its director. In 1916, Einstein was elected president of the German Physical Society (1916–1918).

In 1911, Einstein used his 1907 equivalence principle to calculate the deflection of light from another star by the Sun's gravity. In 1913, Einstein improved upon those calculations by using the curvature of spacetime to represent the gravity field. By the fall of 1915, Einstein had successfully completed his general theory of relativity, which he used to calculate that deflection, and the perihelion precession of Mercury.

In 1919, that deflection prediction was confirmed by Sir Arthur Eddington during the solar eclipse of 29 May 1919. Those observations were published in the international media, making Einstein world-famous.

On 7 November 1919, the leading British newspaper The Times printed a banner headline that read: "Revolution in Science – New Theory of the Universe – Newtonian Ideas Overthrown".

In 1920, he became a Foreign Member of the Royal Netherlands Academy of Arts and Sciences.

In 1922, he was awarded the 1921 Nobel Prize in Physics "for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect".

While the general theory of relativity was still considered somewhat controversial, the citation also does not treat even the cited photoelectric work as an explanation but merely as a discovery of the law, as the idea of photons was considered outlandish and did not receive universal acceptance until the 1924 derivation of the Planck spectrum by S. N. Bose.

Einstein was elected a Foreign Member of the Royal Society (ForMemRS) in 1921. He also received the Copley Medal from the Royal Society in 1925.

Einstein resigned from the Prussian Academy in March 1933. Einstein's scientific accomplishments while in Berlin, included finishing the general theory of relativity, proving the Einstein–de Haas effect, contributing to the quantum theory of radiation, and Bose–Einstein statistics.

1921–1922: Travels abroad

Einstein visited New York City for the first time on 2 April 1921, where he received an official welcome by Mayor John Francis Hylan, followed by three weeks of lectures and receptions.

He went on to deliver several lectures at Columbia University and Princeton University, and in Washington, he accompanied representatives of the National Academy of Sciences on a visit to the White House.

On his return to Europe he was the guest of the British statesman and philosopher Viscount Haldane in London, where

he met several renowned scientific, intellectual, and political figures, and delivered a lecture at King's College London. He also published an essay, "My First Impression of the U.S.A.", in July 1921, in which he tried briefly to describe some characteristics of Americans, much as had Alexis de Tocqueville, who published his own impressions in Democracy in America (1835).

For some of his observations, Einstein was clearly surprised: "What strikes a visitor is the joyous, positive attitude to life ... The American is friendly, self-confident, optimistic, and without envy."

In 1922, his travels took him to Asia and later to Palestine, as part of a six-month excursion and speaking tour, as he visited Singapore, Ceylon and Japan, where he gave a series of lectures to thousands of Japanese. After his first public lecture, he met the emperor and empress at the Imperial Palace, where thousands came to watch.

In a letter to his sons, he described his impression of the Japanese as being modest, intelligent, considerate, and having a true feel for art.

In his own travel diaries from his 1922–23 visit to Asia, he expresses some views on the Chinese, Japanese and Indian people, which have been described as xenophobic and racist judgments when they were rediscovered in 2018.

Because of Einstein's travels to the Far East, he was unable to personally accept the Nobel Prize for Physics at the Stockholm award ceremony in December 1922.

In his place, the banquet speech was made by a German diplomat, who praised Einstein not only as a scientist but also as an international peacemaker and activist. On his return voyage, he visited Palestine for 12 days, his only visit to that region.

He was greeted as if he were a head of state, rather than a physicist, which included a cannon salute upon arriving at the home of the British high commissioner, Sir Herbert Samuel. During one reception, the building was stormed by people who wanted to see and hear him.

In Einstein's talk to the audience, he expressed happiness that the Jewish people were beginning to be recognized as a force in the world.

Einstein visited Spain for two weeks in 1923, where he briefly met Santiago Ramón y Cajal and also received a diploma from King Alfonso XIII naming him a member of the Spanish Academy of Sciences.

Albert Einstein at a session of the International Committee on Intellectual Cooperation (League of Nations) of which he was a member from 1922 to 1932, From 1922 to 1932, Einstein was a member of the International Committee on Intellectual Cooperation of the League of Nations in Geneva (with a few months of interruption in 1923–1924), a body created to promote international exchange between scientists, researchers, teachers, artists, and intellectuals.

Originally slated to serve as the Swiss delegate, Secretary-General Eric Drummond was persuaded by Catholic activists Oskar Halecki and Giuseppe Motta to instead have him become

the German delegate, thus allowing Gonzague de Reynold to take the Swiss spot, from which he promoted traditionalist Catholic values. Einstein's former physics professor Hendrik Lorentz and the Polish chemist Marie Curie were also members of the committee.

1925: Visit to South America

In the months of March and April 1925, Einstein visited South America, where he spent about a month in Argentina, a week in Uruguay, and a week in Rio de Janeiro, Brazil.

Einstein's visit was initiated by Jorge Duclout (1856–1927) and Mauricio Nirenstein (1877–1935) with the support of several Argentine scholars, including Julio Rey Pastor, Jakob Laub, and Leopoldo Lugones.

The visit by Einstein and his wife was financed primarily by the Council of the University of Buenos Aires and the Asociación Hebraica Argentina (Argentine Hebraic Association) with a smaller contribution from the Argentine-Germanic Cultural Institution.

1930–1931: Travel to the US

In December 1930, Einstein visited America for the second time, originally intended as a two-month working visit as a research fellow at the California Institute of Technology. After the national attention he received during his first trip to the US, he and his arrangers aimed to protect his privacy.

Although swamped with telegrams and invitations to receive awards or speak publicly, he declined them all.

After arriving in New York City, Einstein was taken to various places and events, including Chinatown, a lunch with the editors of The New York Times, and a performance of Carmen at the Metropolitan Opera, where he was cheered by the audience on his arrival.

During the days following, he was given the keys to the city by Mayor Jimmy Walker and met the president of Columbia University, who described Einstein as "the ruling monarch of the mind". Harry Emerson Fosdick, pastor at New York's Riverside Church, gave Einstein a tour of the church and showed him a full-size statue that the church made of Einstein, standing at the entrance.

Also during his stay in New York, he joined a crowd of 15,000 people at Madison Square Garden during a Hanukkah celebration.

Einstein next traveled to California, where he met Caltech president and Nobel laureate Robert A. Millikan. His friendship with Millikan was "awkward", as Millikan "had a penchant for patriotic militarism", where Einstein was a pronounced pacifist.

During an address to Caltech's students, Einstein noted that science was often inclined to do more harm than good.

This aversion to war also led Einstein to befriend author Upton Sinclair and film star Charlie Chaplin, both noted for their pacifism. Carl Laemmle, head of Universal Studios, gave Einstein a tour of his studio and introduced him to Chaplin. They had an instant rapport, with Chaplin inviting Einstein and his wife, Elsa, to his home for dinner.

Chaplin said Einstein's outward persona, calm and gentle, seemed to conceal a "highly emotional temperament", from which came his "extraordinary intellectual energy".

Chaplin's film, City Lights, was to premiere a few days later in Hollywood, and Chaplin invited Einstein and Elsa to join him as his special guests. Walter Isaacson, Einstein's biographer, described this as "one of the most memorable scenes in the new era of celebrity".

Chaplin visited Einstein at his home on a later trip to Berlin and recalled his "modest little flat" and the piano at which he had begun writing his theory. Chaplin speculated that it was "possibly used as kindling wood by the Nazis".

1933: Emigration to the US

In February 1933, while on a visit to the United States, Einstein knew he could not return to Germany with the rise to power of the Nazis under Germany's new chancellor, Adolf Hitler.

While at American universities in early 1933, he undertook his third two-month visiting professorship at the California Institute of Technology in Pasadena. In February and March 1933, the Gestapo repeatedly raided his family's apartment in Berlin.

He and his wife Elsa returned to Europe in March, and during the trip, they learned that the German Reichstag had passed the Enabling Act on 23 March, transforming Hitler's government into a de facto legal dictatorship, and that they would not be able to proceed to Berlin. Later on, they heard that their cottage had been raided by the Nazis and Einstein's personal sailboat confiscated.

Upon landing in Antwerp, Belgium on 28 March, Einstein immediately went to the German consulate and surrendered his passport, formally renouncing his German citizenship. The Nazis later sold his boat and converted his cottage into a Hitler Youth camp.

Refugee status

In April 1933, Einstein discovered that the new German government had passed laws barring Jews from holding any official positions, including teaching at universities. Historian Gerald Holton describes how, with "virtually no audible protest being raised by their colleagues", thousands of Jewish scientists were suddenly forced to give up their university positions and their names were removed from the rolls of institutions where they were employed.

A month later, Einstein's works were among those targeted by the German Student Union in the Nazi book burnings, with Nazi propaganda minister Joseph Goebbels proclaiming, "Jewish intellectualism is dead." One German magazine included him in a list of enemies of the German regime with the phrase, "not yet hanged", offering a $5,000 bounty on his head. In a subsequent letter to physicist and friend Max Born, who had already emigrated from Germany to England, Einstein wrote, ... I must confess that the degree of their brutality and cowardice came as something of a surprise.

After moving to the US, he described the book burnings as a "spontaneous emotional outburst" by those who "shun popular enlightenment", and "more than anything else in the world, fear the influence of men of intellectual independence".

Einstein was now without a permanent home, unsure where he would live and work, and equally worried about the fate of countless other scientists still in Germany.

Aided by the Academic Assistance Council, founded in April 1933 by British liberal politician William Beveridge to help academics escape Nazi persecution, Einstein was able to leave Germany. He rented a house in De Haan, Belgium, where he lived for a few months. In late July 1933, he went to England for about six weeks at the personal invitation of British naval officer Commander Oliver Locker-Lampson, who had become friends with Einstein in the preceding years.

Locker-Lampson invited him to stay near his Cromer home in a wooden cabin on Roughton Heath in the Parish of Roughton, Norfolk.

To protect Einstein, Locker-Lampson had two bodyguards watch over him at his secluded cabin; a photo of them carrying shotguns and guarding Einstein was published in the Daily Herald on 24 July 1933.

Resident scholar at the Institute for Advanced Study

On 3 October 1933, Einstein delivered a speech on the importance of academic freedom before a packed audience at the Royal Albert Hall in London, with The Times reporting he was wildly cheered throughout.

Four days later he returned to the US and took up a position at the Institute for Advanced Study, noted for having become a refuge for scientists fleeing Nazi Germany.

At the time, most American universities, including Harvard, Princeton and Yale, had minimal or no Jewish faculty or students, as a result of their Jewish quotas, which lasted until the late 1940s.

Einstein was still undecided on his future. He had offers from several European universities, including Christ Church, Oxford, where he stayed for three short periods between May 1931 and June 1933 and was offered a five-year research fellowship (called a "studentship" at Christ Church), but in 1935, he arrived at the decision to remain permanently in the United States and apply for citizenship.

Einstein's affiliation with the Institute for Advanced Study would last until his death in 1955.

He was one of the four first selected (along with John von Neumann, Kurt Gödel, and Hermann Weyl at the new Institute. He soon developed a close friendship with Gödel; the two would take long walks together discussing their work.

Bruria Kaufman, his assistant, later became a physicist. During this period, Einstein tried to develop a unified field theory and to refute the accepted interpretation of quantum physics, both unsuccessfully.

World War II and the Manhattan Project

In 1939, a group of Hungarian scientists that included émigré physicist Leó Szilárd attempted to alert Washington to ongoing Nazi atomic bomb research. The group's warnings were discounted.

Einstein and Szilárd, along with other refugees such as Edward Teller and Eugene Wigner, "regarded it as their responsibility to alert Americans to the possibility that German scientists might win the race to build an atomic bomb, and to warn that Hitler would be more than willing to resort to such a weapon."

To make certain the US was aware of the danger, in July 1939, a few months before the beginning of World War II in Europe, Szilárd and Wigner visited Einstein to explain the possibility of atomic bombs, which Einstein, a pacifist, said he had never considered.

He was asked to lend his support by writing a letter, with Szilárd, to President Roosevelt, recommending the US pay attention and engage in its own nuclear weapons research.

The letter is believed to be "arguably the key stimulus for the U.S. adoption of serious investigations into nuclear weapons on the eve of the U.S. entry into World War II".

In addition to the letter, Einstein used his connections with the Belgian Royal Family and the Belgian queen mother to get access with a personal envoy to the White House's Oval Office.

Some say that as a result of Einstein's letter and his meetings with Roosevelt, the US entered the "race" to develop the bomb, drawing on its "immense material, financial, and scientific resources" to initiate the Manhattan Project.

For Einstein, "war was a disease ... he called for resistance to war." By signing the letter to Roosevelt, some argue he went against his pacifist principles.

In 1954, a year before his death, Einstein said to his old friend, Linus Pauling, "I made one great mistake in my life—when I signed the letter to President Roosevelt recommending that atom bombs be made; but there was some justification—the danger that the Germans would make them ..."

In 1955, Einstein and ten other intellectuals and scientists, including British philosopher Bertrand Russell, signed a manifesto highlighting the danger of nuclear weapons.

About Charles Darwin

Charles Darwin, in full Charles Robert Darwin, (born February 12, 1809, Shrewsbury, Shropshire, England—died April 19, 1882, Downe, Kent), English naturalist whose scientific theory of evolution by natural selection became the foundation of modern evolutionary studies.

An affable country gentleman, Darwin at first shocked religious Victorian society by suggesting that animals and humans shared a common ancestry.

However, his nonreligious biology appealed to the rising class of professional scientists, and by the time of his death evolutionary imagery had spread through all of science, literature, and politics.

Darwin, himself an agnostic, was accorded the ultimate British accolade of burial in Westminster Abbey, London.

Darwin formulated his bold theory in private in 1837–39, after returning from a voyage around the world aboard HMS Beagle, but it was not until two decades later that he finally gave it full public expression in On the Origin of Species (1859), a book

that has deeply influenced modern Western society and thought.

Early life and education

Darwin was the second son of society doctor Robert Waring Darwin and of Susannah Wedgwood, daughter of the Unitarian pottery industrialist Josiah Wedgwood.

Darwin's other grandfather, Erasmus Darwin, a freethinking physician and poet fashionable before the French Revolution, was author of Zoonomia; or the Laws of Organic Life (1794–96). Darwin's mother died when he was eight, and he was cared for by his three elder sisters. The boy stood in awe of his overbearing father, whose astute medical observations taught him much about human psychology. But he hated the rote learning of Classics at the traditional Anglican Shrewsbury School, where he studied between 1818 and 1825.

Science was then considered dehumanizing in English public schools, and for dabbling in chemistry Darwin was condemned by his headmaster (and nicknamed "Gas" by his schoolmates).

His father, considering the 16-year-old a wastrel interested only in game shooting, sent him to study medicine at Edinburgh University in 1825. Later in life, Darwin gave the impression that he had learned little during his two years at Edinburgh.

In fact, it was a formative experience. There was no better science education in a British university.

He was taught to understand the chemistry of cooling rocks on the primitive Earth and how to classify plants by the modern "natural system."

At the Edinburgh Museum he was taught to stuff birds by John Edmonstone, a freed South American slave, and to identify the rock strata and colonial flora and fauna.

More crucially, the university’s radical students exposed the teenager to the latest Continental sciences. Edinburgh attracted English Dissenters who were barred from graduating at the Anglican universities of Oxford and Cambridge, and at student societies Darwin heard freethinkers deny the Divine design of human facial anatomy and argue that animals shared all the human mental faculties.

One talk, on the mind as the product of a material brain, was officially censored, for such materialism was considered subversive in the conservative decades after the French Revolution.

Darwin was witnessing the social penalties of holding deviant views. As he collected sea slugs and sea pens on nearby shores, he was accompanied by Robert Edmond Grant, a radical evolutionist and disciple of the French biologist Jean-Baptiste Lamarck.

An expert on sponges, Grant became Darwin’s mentor, teaching him about the growth and relationships of primitive marine invertebrates, which Grant believed held the key to unlocking the mysteries surrounding the origin of more-complex creatures.

Darwin, encouraged to tackle the larger questions of life through a study of invertebrate zoology, made his own observations on the larval sea mat (Flustra) and announced his findings at the student societies.

The young Darwin learned much in Edinburgh's rich intellectual environment, but not medicine: he loathed anatomy, and (pre-chloroform) surgery sickened him.

His freethinking father, shrewdly realizing that the church was a better calling for an aimless naturalist, switched him to Christ's College, Cambridge, in 1828.

In a complete change of environment, Darwin was now educated as an Anglican gentleman. He took his horse, indulged his drinking, shooting, and beetle-collecting passions with other squires' sons, and managed 10th place in the Bachelor of Arts degree in 1831.

Here he was shown the conservative side of botany by a young professor, the Reverend John Stevens Henslow, while that doyen of Providential design in the animal world, the Reverend Adam Sedgwick, took Darwin to Wales in 1831 on a geologic field trip.

Fired by Alexander von Humboldt's account of the South American jungles in his Personal Narrative of Travels, Darwin jumped at Henslow's suggestion of a voyage to Tierra del Fuego, at the southern tip of South America, aboard a rebuilt brig, HMS Beagle.

Darwin would not sail as a lowly surgeon-naturalist but as a self-financed gentleman companion to the 26-year-old captain, Robert Fitzroy, an aristocrat who feared the loneliness of command.

Fitzroy's was to be an imperial-evangelical voyage: he planned to survey coastal Patagonia to facilitate British trade and return

three “savages” previously brought to England from Tierra del Fuego and Christianized. Darwin equipped himself with weapons, books (Fitzroy gave him the first volume of Principles of Geology, by Charles Lyell), and advice on preserving carcasses from London Zoo’s experts. The Beagle sailed from England on December 27, 1831.

The Beagle voyage of Charles Darwin

The circumnavigation of the globe would be the making of the 22-year-old Darwin. Five years of physical hardship and mental rigour, imprisoned within a ship’s walls, offset by wide-open opportunities in the Brazilian jungles and the Andes Mountains, were to give Darwin a new seriousness. As a gentleman naturalist, he could leave the ship for extended periods, pursuing his own interests. As a result, he spent only 18 months of the voyage aboard the ship.

The hardship was immediate: a tormenting seasickness. And so was his questioning: on calm days Darwin’s plankton-filled townet left him wondering why beautiful creatures teemed in the ocean’s vastness, where no human could appreciate them. On the Cape Verde Islands (January 1832), the sailor saw bands of oyster shells running through local rocks, suggesting that Lyell was right in his geologic speculations and that the land was rising in places, falling in others.

At Salvador de Bahia (now Salvador), Brazil, the luxuriance of the rainforest left Darwin’s mind in “a chaos of delight.” But that mind, with its Wedgwood-abolitionist characteristics, was revolted by the local slavery.

For Darwin, so often alone, the tropical forests seemed to compensate for human evils: months were spent in Rio de Janeiro amid that shimmering tropical splendour, full of "gaily-coloured" flatworms, and the collector himself became "red-hot with Spiders." But nature had its own evils, and Darwin always remembered with a shudder the parasitic ichneumon wasp, which stored caterpillars to be eaten alive by its grubs. He would later consider that evidence against the beneficent design of nature.

On the River Plate (Río de la Plata) in July 1832, he found Montevideo, Uruguay, in a state of rebellion and joined armed sailors to retake the rebel-held fort. At Bahía Blanca, Argentina, gauchos told him of their extermination of the Pampas "Indians."

Beneath the veneer of human civility, genocide seemed the rule on the frontier, a conclusion reinforced by Darwin's meeting with General Juan Manuel de Rosas and his "villainous Banditti-like army," in charge of eradicating the natives.

For a sensitive young man, fresh from Christ's College, that was disturbing. His contact with "untamed" humans on Tierra del Fuego in December 1832 unsettled him more. How great, wrote Darwin, the "difference between savage & civilized man is. It is greater than between a wild & domesticated animal." God had evidently created humans in a vast cultural range, and yet, judging by the Christianized savages aboard, even the "lowest" races were capable of improvement.

Darwin was tantalized, and always he niggled for explanations.

His fossil discoveries raised more questions. Darwin's periodic trips over two years to the cliffs at Bahía Blanca and farther south at Port St. Julian yielded huge bones of extinct mammals. Darwin manhandled skulls, femurs, and armour plates back to the ship—relics, he assumed, of rhinoceroses, mastodons, cow-sized armadillos, and giant ground sloths (such as Megatherium). He unearthed a horse-sized mammal with a long face like an anteater's, and he returned from a 340-mile (550-km) ride to Mercedes near the Uruguay River with a skull 28 inches (71 cm) long strapped to his horse.

Fossil extraction became a romance for Darwin. It pushed him into thinking of the primeval world and what had caused those giant beasts to die out.

The land was evidently changing, rising; Darwin's observations in the Andes Mountains confirmed it. After the Beagle surveyed the Falkland Islands, and after Darwin had packed away at Port Desire (Puerto Deseado), Argentina, the partially gnawed bones of a new species of small rhea, the ship sailed up the west coast of South America to Valparaíso, Chile.

Here Darwin climbed 4,000 feet (1,200 metres) into the Andean foothills and marveled at the forces that could raise such mountains. The forces themselves became tangible when he saw volcanic Mount Osorno erupt on January 15, 1835.

Then in Valdivia, Chile, on February 20, as he lay on a forest floor, the ground shook: the violence of the earthquake and ensuing tidal wave was enough to destroy the great city of Concepción, whose rubble Darwin walked through.

But what intrigued him was the seemingly insignificant: the local mussel beds, all dead, were now lying above high tide. The land had risen: Lyell, taking the uniformitarian position, had argued that geologic formations were the result of steady cumulative forces of the sort we see today.

And Darwin had seen them. The continent was thrusting itself up, a few feet at a time. He imagined the eons it had taken to raise the fossilized trees in sandstone (once seashore mud) to 7,000 feet (2,100 meters), where he found them. Darwin began thinking in terms of deep time.

They left Peru on the circumnavigation home in September 1835. First Darwin landed on the “frying hot” Galapagos Islands. Those were volcanic prison islands, crawling with marine iguanas and giant tortoises.

(Darwin and the crew brought small tortoises aboard as pets, to join their coatis from Peru)

Contrary to legend, those islands never provided Darwin’s “eureka” moment. Although he noted that the mockingbirds differed on four islands and tagged his specimens accordingly, he failed to label his other birds—what he thought were wrens, “gross-beaks,” finches, and oriole-relatives—by island. Nor did Darwin collect tortoise specimens, even though local prisoners believed that each island had its distinct race.

The “home-sick heroes” returned via Tahiti, New Zealand, and Australia. By April 1836, when the Beagle made the Cocos (Keeling) Islands in the Indian Ocean—Fitzroy’s brief being to see if coral reefs sat on mountain tops—Darwin already had his theory of reef formation.

He imagined (correctly) that those reefs grew on sinking mountain rims. The delicate coral built up, compensating for the drowning land, so as to remain within optimal heat and lighting conditions.

At the Cape of Good Hope, Darwin talked with the astronomer Sir John Herschel, possibly about Lyell's gradual geologic evolution and perhaps about how it entailed a new problem, the "mystery of mysteries," the simultaneous change of fossil life.

On the last leg of the voyage Darwin finished his 770-page diary, wrapped up 1,750 pages of notes, drew up 12 catalogs of his 5,436 skins, bones, and carcasses—and still he wondered: Was each Galapagos mockingbird a naturally produced variety? Why did ground sloths become extinct?

He sailed home with problems enough to last him a lifetime. When he landed in October 1836, the vicarage had faded, the gun had given way to the notebook, and the supreme theorizer—who would always move from small causes to big outcomes—had the courage to look beyond the conventions of his own Victorian culture for new answers.

Evolution by natural selection: The London years, 1836–42

With his voyage over and with a £400 annual allowance from his father, Darwin now settled down among the urban gentry as a gentleman geologist.

He befriended Lyell, and he discussed the rising Chilean coastline as a new fellow of the Geological Society in January 1837 (he was secretary of the society by 1838).

Darwin became well known through his diary's publication as Journal of Researches into the Geology and Natural History of the Various Countries Visited by H.M.S. Beagle (1839).

With a £1,000 Treasury grant, obtained through the Cambridge network, he employed the best experts and published their descriptions of his specimens in his Zoology of the Voyage of H.M.S. Beagle (1838–43). Darwin's star had risen, and he was now lionized in London.

It was in those years of civil unrest following the First Reform Act (1832) that Darwin devised his theory of evolution. Radical nonconformists were denouncing the church's monopoly on power—attacking an Anglican status quo that rested on miraculous props: the supposed supernatural creation of life and society.

Darwin had Unitarian roots, and his breathless notes show how his radical Dissenting understanding of equality and antislavery framed his image of mankind's place in nature: "Animals—whom we have made our slaves we do not like to consider our equals. Do not slave holders wish to make the black man other kind?"

Some radicals questioned whether each animal was uniquely "designed" by God when all vertebrates shared a similar structural plan.

The polymathic Charles Babbage—of calculating machine fame—made God a divine programmer, preordaining life by means of natural law rather than ad hoc miracle.

It was the ultra-Whig way, and in 1837 Darwin, an impeccable Whig reformer who enjoyed Babbage's soirees, likewise accepted that "the Creator creates by…laws."

The experts' findings sent Darwin to more-heretical depths. At the Royal College of Surgeons, the eminent anatomist Richard Owen found that Darwin's Uruguay River skull belonged to Toxodon, a hippopotamus-sized antecedent of the South American capybara.

The Pampas fossils were nothing like rhinoceroses and mastodons; they were huge extinct armadillos, anteaters, and sloths, which suggested that South American mammals had been replaced by their own kind according to some unknown "law of succession."

At the Zoological Society, ornithologist John Gould announced that the Galapagos birds were not a mixture of wrens, finches, and "gross-beaks" but were all ground finches, differently adapted. When Gould diagnosed the Galapagos mockingbirds as three species, unique to different islands, in March 1837, Darwin examined Fitzroy's collection to discover that each island had its representative finch as well.

But how had they all diverged from mainland colonists? By that time Darwin was living near his freethinking brother, Erasmus, in London's West End, and their dissident dining circle, which included the Unitarian Harriet Martineau, provided the perfect milieu for Darwin's ruminations.

Darwin adopted "transmutation" (evolution, as it is now called), perhaps because of his familiarity with it through the work of his grandfather and Robert Grant.

Nonetheless, it was abominated by the Cambridge clerics as a bestial, if not blasphemous, heresy that would corrupt mankind and destroy the spiritual safeguards of the social order. Thus began Darwin's double life, which would last for two decades.

For two years he filled notebooks with jottings. There was an intensity and doggedness to it. He searched for the causes of extinction, accepted life as a branching tree (not a series of escalators, the old idea), tackled island isolation, and wondered whether variations appeared gradually or at a stroke. He dismissed a Lamarckian force driving life inexorably upward with the cavalier joke, "If all men were dead then monkeys make men. —Men make angels," which showed how little the failed ordained shared his Cambridge mentors' hysteria about an ape ancestry.

Indeed, there was no "upward": he became relativistic, sensing that life was spreading outward into niches, not standing on a ladder. There was no way of ranking humans and bees, no yardstick of "highness": man was no longer the crown of creation.

Heart palpitations and stomach problems were affecting him by September 1837. Stress sent him to the Highlands of Scotland in 1838, where he diverted himself studying the "parallel roads" of Glen Roy, so like the raised beaches in Chile. But the sickness returned as he continued chipping at the scientific bedrock of a cleric-dominated society. The "whole [miraculous] fabric totters & falls," he jotted.

Darwin had a right to be worried. Were his secret discovered, he would stand accused of social abandon.

At Edinburgh he had seen censorship; other materialists were being publicly disgraced. His notes began mooting disarming ploys: “Mention persecution of early astronomers.” Behind his respectable facade at the Geological Society lay a new contempt for the divines’ providential shortsightedness.

The president, the Reverend William Whewell, “says length of days adapted to duration of sleep of man.!!!” he jotted. What “arrogance!!”

Mankind: there was the crux. Darwin wrote humans and society into the evolutionary equation from the start. He saw the social instincts of troop animals developing into morality and studied the humanlike behaviour of orangutans at the zoo.

With avant-garde society radicalized, Darwin moved into his own ultraradical phase in 1838—even suggesting that belief in God was an ingrained tribal survival strategy: “love of [the] deity [is an] effect of [the brain’s] organization.

Oh you Materialist!” he mocked himself. In a day when a gentleman’s character had to be above reproach, Darwin’s notes had a furtive ring. None of that could become known—yet.

The rich careerist—admitted to the prestigious Athenaeum Club in 1838 and the Royal Society in 1839—had too much to lose.

As a sporting gent from the shires, Darwin queried breeders about the way they changed domestic dogs and fancy pigeons by spotting slight variations and accentuating them through breeding.

But he only saw the complete congruity between the way nature operated and the way fanciers produced new breeds upon reading the economist Thomas Malthus's Essay on the Principle of Population in September 1838.

That was a seminal moment—even if Malthusian ideas had long permeated his Whig circle. Darwin was living through a workhouse revolution. Malthus had said that there would always be too many mouths to feed—population increases geometrically, whereas food production rises arithmetically—and that charity was useless.

So the Whigs had passed a Malthusian Poor Law in 1834 and were incarcerating sick paupers in workhouses (separating men from women to stop them from breeding). Darwin's dining companion Harriet Martineau (whom many expected to marry his brother, Erasmus), was the Whigs' poor law propagandist.

(Her novelistic Malthusian pamphlets had been sent to Darwin while he was on the Beagle)

Darwin realized that population explosions would lead to a struggle for resources and that the ensuing competition would weed out the unfit. It was an idea he now applied to nature (he had previously thought that animal populations remained stable in the wild). Darwin called his modified Malthusian mechanism "natural selection." Nature was equally uncharitable, went the argument: overpopulated, it experienced a fierce struggle, and from all manner of chance variations, good and bad, the best, "the surviving one of ten thousand trials," won out, endured, and thus passed on its improved trait.

That was the way a species kept pace with the Lyellian evolution of Earth.

Darwin was a born list maker. In 1838 he even totted up the pros and cons of taking a wife—and married his cousin Emma Wedgwood (1808–96) in 1839.

He rashly confided his thoughts on evolution, evidently shocking her. By now, Darwin accepted the notion that even mental traits and instincts were randomly varying, that they were the stuff for selection. But he saw from Emma's reaction that he must publicly camouflage his views.

Although the randomness and destructiveness of his evolutionary system—with thousands dying so that the "fittest" might survive—left little room for a personally operating benign deity, Darwin still believed that God was the ultimate lawgiver of the universe. In 1839 he shut his last major evolution notebook, his theory largely complete.

The squire naturalist in Downe

Darwin drafted a 35-page sketch of his theory of natural selection in 1842 and expanded it in 1844, but he had no immediate intention of publishing it. He wrote Emma a letter in 1844 requesting that, if he died, she should pay an editor £400 to publish the work.

Perhaps he wanted to die first. In 1842, Darwin, increasingly shunning society, had moved the family to the isolated village of Downe, in Kent, at the "extreme edge of the world."

(It was in fact only 16 miles [26 km] from central London)

Here, living in a former parsonage, Down House, he emulated the lifestyle of his clerical friends. Fearing prying eyes, he even lowered the road outside his house.

His seclusion was complete: from now on he ran his days like clockwork, with set periods for walking, napping, reading, and nightly backgammon. He fulfilled his parish responsibilities, eventually helping to run the local Coal and Clothing Club for the labourers.

His work hours were given over to bees, flowers, and barnacles and to his books on coral reefs and South American geology, three of which in 1842–46 secured his reputation as a career geologist.

He rarely mentioned his secret. When he did, notably to the Kew Gardens botanist Joseph Dalton Hooker, Darwin said that believing in evolution was “like confessing a murder.” The analogy with that capital offense was not so strange: seditious atheists were using evolution as part of their weaponry against Anglican oppression and were being jailed for blasphemy.

Darwin, nervous and nauseous, trying spas and quack remedies (even tying plate batteries to his heaving stomach), understood the conservative clerical morality. He was sensitive to the offense he might cause.

He was also immensely wealthy: by the late 1840s the Darwins had £80,000 invested; he was an absentee landlord of two large Lincolnshire farms; and in the 1850s he plowed tens of thousands of pounds into railway shares.

Even though his theory, with its capitalist and meritocratic emphasis, was quite unlike anything touted by the radicals and rioters, those turbulent years were no time to break cover.

From 1846 to 1854, Darwin added to his credibility as an expert on species by pursuing a detailed study of all known barnacles. Intrigued by their sexual differentiation, he discovered that some females had tiny degenerate males clinging to them.

That sparked his interest in the evolution of diverging male and female forms from an original hermaphrodite creature. Four monographs on such an obscure group made him a world expert and gained him the Royal Society's Royal Medal in 1853. No longer could he be dismissed as a speculator on biological matters.

On the Origin of Species

England became quieter and more prosperous in the 1850s, and by mid-decade the professionals were taking over, instituting exams and establishing a meritocracy.

The changing social composition of science—typified by the rise of the freethinking biologist Thomas Henry Huxley—promised a better reception for Darwin.

Huxley, the philosopher Herbert Spencer, and other outsiders were opting for a secular nature in the rationalist Westminster Review and deriding the influence of "parsondom."

Darwin had himself lost the last shreds of his belief in Christianity with the tragic death of his oldest daughter, Annie, from typhoid in 1851.

The world was becoming safer for Darwin and his theory: mid-Victorian England was stabler than the “hungry Thirties” or turbulent 1840s. In 1854 he solved his last major problem, the forking of genera to produce new evolutionary branches.

He used an industrial analogy familiar from the Wedgwood factories, the division of labour: competition in nature’s overcrowded marketplace would favour variants that could exploit different aspects of a niche. Species would diverge on the spot, like tradesmen in the same tenement.

Through 1855 Darwin experimented with seeds in seawater, to prove that they could survive ocean crossings to start the process of speciation on islands. Then he kept fancy pigeons, to see if the chicks were more like the ancestral rock dove than their own bizarre parents.

Darwin perfected his analogy of natural selection with the fancier’s “artificial selection,” as he called it. He was preparing his rhetorical strategy, ready to present his theory.

After speaking to Huxley and Hooker at Downe in April 1856, Darwin began writing a triple-volume book, tentatively called Natural Selection, which was designed to crush the opposition with a welter of facts.

Darwin now had immense scientific and social authority, and his place in the parish was assured when he was sworn in as a justice of the peace in 1857. Encouraged by Lyell, Darwin continued writing through the birth of his 10th and last child, Charles Waring Darwin (born in 1856, when Emma was 48), who was developmentally disabled.

Whereas in the 1830s Darwin had thought that species remained perfectly adapted until the environment changed, he now believed that every new variation was imperfect, and that perpetual struggle was the rule. He also explained the evolution of sterile worker bees in 1857.

Those could not be selected because they did not breed, so he opted for “family” selection (kin selection, as it is known today): the whole colony benefited from their retention.

Darwin had finished a quarter of a million words by June 18, 1858. That day he received a letter from Alfred Russel Wallace, an English socialist and specimen collector working in the Malay Archipelago, sketching a similar-looking theory.

Darwin, fearing loss of priority, accepted Lyell’s and Hooker’s solution: they read joint extracts from Darwin’s and Wallace’s works at the Linnean Society on July 1, 1858.

Darwin was away, sick, grieving for his tiny son who had died from scarlet fever, and thus he missed the first public presentation of the theory of natural selection. It was an absenteeism that would mark his later years.

Darwin hastily began an “abstract” of Natural Selection, which grew into a more-accessible book, On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.

Suffering from a terrible bout of nausea, Darwin, now 50, was secreted away at a spa on the desolate Yorkshire moors when the book was sold to the trade on November 22, 1859.

He still feared the worst and sent copies to the experts with self-effacing letters ("how you will long to crucify me alive"). It was like "living in Hell," he said about those months.

The book did distress his Cambridge patrons, but they were marginal to science now. However, radical Dissenters were sympathetic, as were the rising London biologists and geologists, even if few actually adopted Darwin's cost-benefit approach to nature.

The newspapers drew the one conclusion that Darwin had specifically avoided: that humans had evolved from apes, and that Darwin was denying mankind's immortality. A sensitive Darwin, making no personal appearances, let Huxley, by now a good friend, manage that part of the debate.

The pugnacious Huxley, who loved public argument as much as Darwin loathed it, had his own reasons for taking up the cause, and did so with enthusiasm.

He wrote three reviews of Origin of Species, defended human evolution at the Oxford meeting of the British Association for the Advancement of Science in 1860 (when Bishop Samuel Wilberforce jokingly asked whether the apes were on Huxley's grandmother's or grandfather's side), and published his own book on human evolution, Evidence as to Man's Place in Nature (1863).

What Huxley championed was Darwin's evolutionary naturalism, his nonmiraculous assumptions, which pushed biological science into previously taboo areas and increased the power of Huxley's professionals. And it was they who gained the Royal Society's Copley Medal for Darwin in 1864.

Huxley’s reaction, with its enthusiasm for evolution and cooler opinion of natural selection, was typical. Natural selection—the “law of higgledy-piggledy” in Herschel’s dismissive words—received little support in Darwin’s day. By contrast, evolution itself (“descent,” Darwin called it—the word evolution would only be introduced in the last, 1872, edition of the Origin) was being acknowledged from British Association platforms by 1866.

That year, too, Darwin met his German admirer, the zoologist Ernst Haeckel, whose proselytizing would spread Darwinismus through the Prussian world. Two years later the King of Prussia conferred on Darwin the order Pour le Mérite.

The patriarch in his home laboratory

Long periods of debilitating sickness in the 1860s left the craggy, bearded Darwin thin and ravaged. He once vomited for 27 consecutive days.

Down House was an infirmary where illness was the norm and Emma the attendant nurse. She was a shield, protecting the patriarch, cosseting him.

Darwin was a typical Victorian in his racial and sexual stereotyping—however dependent on his redoubtable wife, he still thought women inferior; and although a fervent abolitionist, he still considered blacks a lower race.

But few outside of the egalitarian socialists challenged those prejudices—and Darwin, immersed in a competitive Whig culture, and enshrining its values in his science, had no time for socialism.

The house was also a laboratory, where Darwin continued experimenting and revamping the Origin through six editions. Although quietly swearing by “my deity ‘Natural Selection,’” he answered critics by reemphasizing other causes of change—for example, the effects of continued use of an organ—and he bolstered the Lamarckian belief that such alterations through excessive use might be passed on.

In Variation of Animals and Plants under Domestication (1868) he marshaled the facts and explored the causes of variation in domestic breeds. The book answered critics such as George Douglas Campbell, the eighth duke of Argyll, who loathed Darwin’s blind, accidental process of variation and envisaged the appearance of “new births” as goal directed.

By showing that fanciers picked from the gamut of naturally occurring variations to produce the tufts and topknots on their fancy pigeons, Darwin undermined this providential explanation.

In 1867 the engineer Fleeming Jenkin argued that any single favourable variation would be swamped and lost by back-breeding within the general population. No mechanism was known for inheritance, and so in the Variation Darwin devised his hypothesis of “pangenesis” to explain the discrete inheritance of traits.

He imagined that each tissue of an organism threw out tiny “gemmules,” which passed to the sex organs and permitted copies of themselves to be made in the next generation. But Darwin’s cousin Francis Galton failed to find those gemmules in rabbit blood, and the theory was dismissed.

Darwin was adept at flanking movements in order to get around his critics. He would take seemingly intractable subjects—like orchids flowers—and make them test cases for “natural selection.” Hence the book that appeared after the Origin was, to everyone’s surprise, The Various Contrivances by which British and Foreign Orchids are Fertilised by Insects (1862).

He showed that the orchid’s beauty was not a piece of floral whimsy “designed” by God to please humans but honed by selection to attract insect cross-pollinators. The petals guided the bees to the nectaries, and pollen sacs were deposited exactly where they could be removed by a stigma of another flower.

But why the importance of cross-pollination? Darwin’s botanical work was always subtly related to his evolutionary mechanism. He believed that cross-pollinated plants would produce fitter offspring than self-pollinators, and he used considerable ingenuity in conducting thousands of crossings to prove the point.

The results appeared in The Effects of Cross and Self Fertilization in the Vegetable Kingdom (1876). His next book, The Different Forms of Flowers on Plants of the Same Species (1877), was again the result of long-standing work into the way evolution in some species favoured different male and female forms of flowers to facilitate outbreeding.

Darwin had long been sensitive to the effects of inbreeding because he was himself married to a Wedgwood cousin, as was his sister Caroline. He agonized over its debilitating consequence for his five sons.

Not that he need have worried, for they fared well: William became a banker, Leonard an army major, George the Plumian Professor of Astronomy at Cambridge, Francis a reader in botany at Cambridge, and Horace a scientific instrument maker.

Darwin also studied insectivorous plants, climbing plants, and the response of plants to gravity and light (sunlight, he thought, activated something in the shoot tip, an idea that guided future work on growth hormones in plants).

The private man and the public debate

Through the 1860s natural selection was already being applied to the growth of society. A.R. Wallace saw cooperation strengthening the moral bonds within primitive tribes. Advocates of social Darwinism, in contrast, complained that modern civilization was protecting the “unfit” from natural selection.

Francis Galton argued that particular character traits—even drunkenness and genius—were inherited and that “eugenics,” as it would come to be called, would stop the genetic drain.

The trend to explain the evolution of human races, morality, and civilization was capped by Darwin in his two-volume The Descent of Man, and Selection in Relation to Sex (1871).

The book was authoritative, annotated, and heavily anecdotal in places.

The two volumes were discrete, the first discussing the evolution of civilization and human origins among the Old World monkeys.

(Darwin's depiction of a hairy human ancestor with pointed ears led to a spate of caricatures)

The second volume responded to critics like Argyll, who doubted that the iridescent hummingbird's plumage had any function—or any Darwinian explanation.

Darwin argued that female birds were choosing mates for their gaudy plumage. Darwin as usual tapped his huge correspondence network of breeders, naturalists, and travelers worldwide to produce evidence for that.

Such "sexual selection" happened among humans too. With primitive societies accepting diverse notions of beauty, aesthetic preferences, he believed, could account for the origin of the human races.

Traditionally, humans were considered the sole recent representatives of the family Hominidae, but recent findings indicate that chimpanzees and bonobos are more closely related to humans than are gorillas and orangutans and that the last common ancestor between the chimpanzee and human lines lived sometime between seven million and six million years ago.

Therefore, all great apes are now gathered with humans into Hominidae, and within that family humans and their extinct ancestors are considered to make up the tribe Hominini.

The term man has traditionally referred to humans in general, or humankind. The idea of man is treated in a number of articles. For a philosophical treatment of the subject, see philosophical anthropology.

For the physical anthropology of human ancestry, . For an examination of human culture, see art; cuisine; dance; government; literature; music; sport.

Death; emotion; family; human behaviour; human rights; intelligence; kinship; language; learning theory; mind, philosophy of; motivation; perception; personality; population; sexual behaviour, human; social structure; Stone Age; technology; thought.

About Marie Curie

Marie Salomea Skłodowska–Curie; 7 November 1867 – 4 July 1934) was a Polish and Naturalized-French physicist and chemist who conducted pioneering research on radioactivity. She was the first woman to win a Nobel Prize, the first person to win a Nobel Prize twice, and the only person to win a Nobel Prize in two scientific fields.

Her husband, Pierre Curie, was a co-winner of her first Nobel Prize, making them the first-ever married couple to win the Nobel Prize and launching the Curie family legacy of five Nobel Prizes. She was, in 1906, the first woman to become a professor at the University of Paris.

She was born in Warsaw, in what was then the Kingdom of Poland, part of the Russian Empire. She studied at Warsaw's clandestine Flying University and began her practical scientific training in Warsaw.

In 1891, aged 24, she followed her elder sister Bronisława to study in Paris, where she earned her higher degrees and conducted her subsequent scientific work.

In 1895 she married the French physicist Pierre Curie, and she shared the 1903 Nobel Prize in Physics with him and with the physicist Henri Becquerel for their pioneering work developing the theory of "radioactivity"—a term she coined.

In 1906 Pierre Curie died in a Paris street accident. Marie won the 1911 Nobel Prize in Chemistry for her discovery of the elements polonium and radium, using techniques she invented for isolating radioactive isotopes.

Under her direction, the world's first studies were conducted into the treatment of neoplasms by the use of radioactive isotopes.

She founded the Curie Institute in Paris in 1920, and the Curie Institute in Warsaw in 1932; both remain major medical research centres. During World War I she developed mobile radiography units to provide X-ray services to field hospitals.

While a French citizen, Marie Skłodowska Curie, who used both surnames, never lost her sense of Polish identity. She taught her daughters the Polish language and took them on visits to Poland. She named the first chemical element she discovered polonium, after her native country.

Marie Curie died in 1934, aged 66, at the Sancellemoz sanatorium in Passy (Haute-Savoie), France, of aplastic anemia likely from exposure to radiation in the course of her scientific research and in the course of her radiological work at field hospitals during World War I.

In addition to her Nobel Prizes, she has received numerous other honours and tributes; in 1995 she became the first woman

to be entombed on her own merits in the Paris Panthéon, and Poland declared 2011 the Year of Marie Curie during the International Year of Chemistry.

She is the subject of numerous biographical works.

Life, Early years

Władysław Skłodowski and daughters (from left) Maria, Bronisława, and Helena, 1890

Maria Skłodowska was born in Warsaw, in Congress Poland in the Russian Empire, on 7 November 1867, the fifth and youngest child of well-known teachers Bronisława, née Boguska, and Władysław Skłodowski.

The elder siblings of Maria (nicknamed Mania) were Zofia (born 1862, nicknamed Zosia), Józef (born 1863, nicknamed Józio), Bronisława (born 1865, nicknamed Bronia) and Helena (born 1866, nicknamed Hela).

On both the paternal and maternal sides, the family had lost their property and fortunes through patriotic involvements in Polish national uprisings aimed at restoring Poland's independence (the most recent had been the January Uprising of 1863–65).

This condemned the subsequent generation, including Maria and her elder siblings, to a difficult struggle to get ahead in life.

Maria's paternal grandfather, Józef Skłodowski, had been principal of the Lublin primary school attended by Bolesław Prus, who became a leading figure in Polish literature.

Władysław Skłodowski taught mathematics and physics, subjects that Maria was to pursue, and was also director of two Warsaw gymnasia (secondary schools) for boys. After Russian authorities eliminated laboratory instruction from the Polish schools, he brought much of the laboratory equipment home and instructed his children in its use.

He was eventually fired by his Russian supervisors for pro-Polish sentiments and forced to take lower-paying posts; the family also lost money on a bad investment and eventually chose to supplement their income by lodging boys in the house.

Maria's mother Bronisława operated a prestigious Warsaw boarding school for girls; she resigned from the position after Maria was born. She died of tuberculosis in May 1878, when Maria was ten years old. Less than three years earlier, Maria's oldest sibling, Zofia, had died of typhus contracted from a boarder.

Maria's father was an atheist, her mother a devout Catholic. The deaths of Maria's mother and sister caused her to give up Catholicism and become agnostic.

When she was ten years old, Maria began attending the boarding school of J. Sikorska; next, she attended a gymnasium for girls, from which she graduated on 12 June 1883 with a gold medal.

After a collapse, possibly due to depression, she spent the following year in the countryside with relatives of her father, and the next year with her father in Warsaw, where she did some tutoring.

Unable to enroll in a regular institution of higher education because she was a woman, she and her sister Bronisława became involved with the clandestine Flying University (sometimes translated as Floating University), a Polish patriotic institution of higher learning that admitted women students.

Maria made an agreement with her sister, Bronisława, that she would give her financial assistance during Bronisława's medical studies in Paris, in exchange for similar assistance two years later.

In connection with this, Maria took a position first as a home tutor in Warsaw, then for two years as a governess in Szczuki with a landed family, the Żorawskis, who were relatives of her father. While working for the latter family, she fell in love with their son, Kazimierz Żorawski, a future eminent mathematician.

His parents rejected the idea of his marrying the penniless relative, and Kazimierz was unable to oppose them. Maria's loss of the relationship with Żorawski was tragic for both. He soon earned a doctorate and pursued an academic career as a mathematician, becoming a professor and rector of Kraków University.

Still, as an old man and a mathematics professor at the Warsaw Polytechnic, he would sit contemplatively before the statue of Maria Skłodowska that had been erected in 1935 before the Radium Institute, which she had founded in 1932.

At the beginning of 1890, Bronisława—who a few months earlier had married Kazimierz Dłuski, a Polish physician and social and political activist—invited Maria to join them in Paris.

Maria declined because she could not afford the university tuition; it would take her a year and a half longer to gather the necessary funds. She was helped by her father, who was able to secure a more lucrative position again. All that time she continued to educate herself, reading books, exchanging letters, and being tutored herself.

In early 1889 she returned home to her father in Warsaw. She continued working as a governess and remained there until late 1891. She tutored, studied at the Flying University, and began her practical scientific training (1890–91) in a chemical laboratory at the Museum of Industry and Agriculture at Krakowskie Przedmieście 66, near Warsaw's Old Town.

The laboratory was run by her cousin Józef Boguski, who had been an assistant in Saint Petersburg to the Russian chemist Dmitri Mendeleev.

Life in Paris

In late 1891, she left Poland for France. In Paris, Maria (or Marie, as she would be known in France) briefly found shelter with her sister and brother-in-law before renting a garret closer to the university, in the Latin Quarter, and proceeding with her studies of physics, chemistry, and mathematics at the University of Paris, where she enrolled in late 1891.

She subsisted on her meagre resources, keeping herself warm during cold winters by wearing all the clothes she had. She focused so hard on her studies that she sometimes forgot to eat. Skłodowska studied during the day and tutored evenings, barely earning her keep.

In 1893, she was awarded a degree in physics and began work in an industrial laboratory of Gabriel Lippmann. Meanwhile, she continued studying at the University of Paris and with the aid of a fellowship she was able to earn a second degree in 1894.

Skłodowska had begun her scientific career in Paris with an investigation of the magnetic properties of various steels, commissioned by the Society for the Encouragement of National Industry.

That same year, Pierre Curie entered her life: it was their mutual interest in natural sciences that drew them together. Pierre Curie was an instructor at The City of Paris Industrial Physics and Chemistry Higher Educational Institution (ESPCI Paris).

They were introduced by Polish physicist Józef Wierusz-Kowalski, who had learned that she was looking for a larger laboratory space, something that Wierusz-Kowalski thought Pierre could access.

Though Curie did not have a large laboratory, he was able to find some space for Skłodowska where she was able to begin work.

Their mutual passion for science brought them increasingly closer, and they began to develop feelings for one another. Eventually, Pierre proposed marriage, but at first Skłodowska did not accept as she was still planning to go back to her native country.

Curie, however, declared that he was ready to move with her to Poland, even if it meant being reduced to teaching French.

Meanwhile, for the 1894 summer break, Skłodowska returned to Warsaw, where she visited her family. She was still labouring under the illusion that she would be able to work in her chosen field in Poland, but she was denied a place at Kraków University because of sexism in academia.

A letter from Pierre convinced her to return to Paris to pursue a Ph.D. At Skłodowska's insistence, Curie had written up his research on magnetism and received his own doctorate in March 1895; he was also promoted to professor at the School. A contemporary quip would call Skłodowska "Pierre's biggest discovery".

On 26 July 1895, they were married in Sceaux; neither wanted a religious service. Curie's dark blue outfit, worn instead of a bridal gown, would serve her for many years as a laboratory outfit.

They shared two pastimes: long bicycle trips and journeys abroad, which brought them even closer. In Pierre, Marie had found a new love, a partner, and a scientific collaborator on whom she could depend.

New elements

In 1895, Wilhelm Röntgen discovered the existence of X-rays, though the mechanism behind their production was not yet understood.

In 1896, Henri Becquerel discovered that uranium salts emitted rays that resembled X-rays in their penetrating power.

He demonstrated that this radiation, unlike phosphorescence, did not depend on an external source of energy but seemed to arise spontaneously from uranium itself.

Influenced by these two important discoveries, Curie decided to look into uranium rays as a possible field of research for a thesis.

She used an innovative technique to investigate samples. Fifteen years earlier, her husband and his brother had developed a version of the electrometer, a sensitive device for measuring electric charge.

Using her husband's electrometer, she discovered that uranium rays caused the air around a sample to conduct electricity.

Using this technique, her first result was the finding that the activity of the uranium compounds depended only on the quantity of uranium present.

She hypothesized that the radiation was not the outcome of some interaction of molecules but must come from the atom itself. This hypothesis was an important step in disproving the assumption that atoms were indivisible.

In 1897, her daughter Irène was born. To support her family, Curie began teaching at the École Normale Supérieure.

The Curies did not have a dedicated laboratory; most of their research was carried out in a converted shed next to ESPCI.

The shed, formerly a medical school dissecting room, was poorly ventilated and not even waterproof.

They were unaware of the deleterious effects of radiation exposure attendant on their continued unprotected work with radioactive substances. ESPCI did not sponsor her research, but she would receive subsidies from metallurgical and mining companies and from various organizations and governments.

Curie's systematic studies included two uranium minerals, pitchblende and torbernite (also known as chalcolite). Her electrometer showed that pitchblende was four times as active as uranium itself, and chalcolite twice as active.

She concluded that, if her earlier results relating the quantity of uranium to its activity were correct, then these two minerals must contain small quantities of another substance that was far more active than uranium.

She began a systematic search for additional substances that emit radiation, and by 1898 she discovered that the element thorium was also radioactive. Pierre Curie was increasingly intrigued by her work. By mid-1898 he was so invested in it that he decided to drop his work on crystals and to join her.

The [research] idea was her own; no one helped her formulate it, and although she took it to her husband for his opinion she clearly established her ownership of it. She later recorded the fact twice in her biography of her husband to ensure there was no chance whatever of any ambiguity. It is likely that already at this early stage of her career she realized that...

many scientists would find it difficult to believe that a woman could be capable of the original work in which she was involved.

She was acutely aware of the importance of promptly publishing her discoveries and thus establishing her priority. Had not Becquerel, two years earlier, presented his discovery to the Académie des Sciences the day after he made it, credit for the discovery of radioactivity (and even a Nobel Prize), would instead have gone to Silvanus Thompson.

Curie chose the same rapid means of publication. Her paper, giving a brief and simple account of her work, was presented for her to the Académie on 12 April 1898 by her former professor, Gabriel Lippmann.

Even so, just as Thompson had been beaten by Becquerel, so Curie was beaten in the race to tell of her discovery that thorium gives off rays in the same way as uranium; two months earlier, Gerhard Carl Schmidt had published his own finding in Berlin.

At that time, no one else in the world of physics had noticed what Curie recorded in a sentence of her paper, describing how much greater were the activities of pitchblende and chalcolite than uranium itself: The fact is very remarkable, and leads to the belief that these minerals may contain an element which is much more active than uranium.

She later would recall how she felt "a passionate desire to verify this hypothesis as rapidly as possible." On 14 April 1898, the Curies optimistically weighed out a 100-gram sample of pitchblende and ground it with a pestle and mortar.

They did not realize at the time that what they were searching for was present in such minute quantities that they would eventually have to process tonnes of the ore.

In July 1898, Curie and her husband published a joint paper announcing the existence of an element they named "polonium", in honour of her native Poland, which would for another twenty years remain partitioned among three empires (Russian, Austrian, and Prussian).

On 26 December 1898, the Curies announced the existence of a second element, which they named "radium", from the Latin word for "ray". In the course of their research, they also coined the word "radioactivity".

To prove their discoveries beyond any doubt, the Curies sought to isolate polonium and radium in pure form. Pitchblende is a complex mineral; the chemical separation of its constituents was an arduous task.

The discovery of polonium had been relatively easy; chemically it resembles the element bismuth, and polonium was the only bismuth-like substance in the ore.

Radium, however, was more elusive; it is closely related chemically to barium, and pitchblende contains both elements. By 1898 the Curies had obtained traces of radium, but appreciable quantities, uncontaminated with barium, were still beyond reach.

The Curies undertook the arduous task of separating out radium salt by differential crystallization. From a tonne of pitchblende, one-tenth of a gram of radium chloride was separated in 1902.

In 1910, she isolated pure radium metal. She never succeeded in isolating polonium, which has a half-life of only 138 days.

Between 1898 and 1902, the Curies published, jointly or separately, a total of 32 scientific papers, including one that announced that, when exposed to radium, diseased, tumour-forming cells were destroyed faster than healthy cells.

In 1900, Curie became the first woman faculty member at the École Normale Supérieure and her husband joined the faculty of the University of Paris. In 1902 she visited Poland on the occasion of her father's death.

In June 1903, supervised by Gabriel Lippmann, Curie was awarded her doctorate from the University of Paris. That month the couple were invited to the Royal Institution in London to give a speech on radioactivity; being a woman, she was prevented from speaking, and Pierre Curie alone was allowed to.

Meanwhile, a new industry began developing, based on radium. The Curies did not patent their discovery and benefited little from this increasingly profitable business.

Nobel Prizes

In December 1903 the Royal Swedish Academy of Sciences awarded Pierre Curie, Marie Curie, and Henri Becquerel the Nobel Prize in Physics, "in recognition of the extraordinary services they have rendered by their joint researches on the radiation phenomena discovered by Professor Henri Becquerel." At first the committee had intended to honour only Pierre Curie and Henri Becquerel, but a committee member and advocate for women scientists, Swedish mathematician Magnus Gösta Mittag-Leffler, alerted Pierre to the situation,

and after his complaint, Marie's name was added to the nomination.

Marie Curie was the first woman to be awarded a Nobel Prize.

Curie and her husband declined to go to Stockholm to receive the prize in person; they were too busy with their work, and Pierre Curie, who disliked public ceremonies, was feeling increasingly ill.

As Nobel laureates were required to deliver a lecture, the Curies finally undertook the trip in 1905.

The award money allowed the Curies to hire their first laboratory assistant. Following the award of the Nobel Prize, and galvanized by an offer from the University of Geneva, which offered Pierre Curie a position, the University of Paris gave him a professorship and the chair of physics, although the Curies still did not have a proper laboratory.

Upon Pierre Curie's complaint, the University of Paris relented and agreed to furnish a new laboratory, but it would not be ready until 1906.

In December 1904, Curie gave birth to their second daughter, Ève.

She hired Polish governesses to teach her daughters her native language, and sent or took them on visits to Poland.

On 19 April 1906, Pierre Curie was killed in a road accident. Walking across the Rue Dauphine in heavy rain, he was struck by a horse-drawn vehicle and fell under its wheels, fracturing his skull and killing him instantly. Curie was devastated by her husband's death.

On 13 May 1906 the physics department of the University of Paris decided to retain the chair that had been created for her late husband and offer it to Marie. She accepted it, hoping to create a world-class laboratory as a tribute to her husband Pierre. She was the first woman to become a professor at the University of Paris.

Curie's quest to create a new laboratory did not end with the University of Paris, however. In her later years, she headed the Radium Institute (Institut du radium, now Curie Institute, Institut Curie), a radioactivity laboratory created for her by the Pasteur Institute and the University of Paris.

The initiative for creating the Radium Institute had come in 1909 from Pierre Paul Émile Roux, director of the Pasteur Institute, who had been disappointed that the University of Paris was not giving Curie a proper laboratory and had suggested that she move to the Pasteur Institute.

Only then, with the threat of Curie leaving, did the University of Paris relent, and eventually the Curie Pavilion became a joint initiative of the University of Paris and the Pasteur Institute.

In 1910 Curie succeeded in isolating radium; she also defined an international standard for radioactive emissions that was eventually named for her and Pierre: the curie. Nevertheless, in 1911 the French Academy of Sciences failed, by one or two votes, to elect her to membership in the academy.

Elected instead was Édouard Branly, an inventor who had helped Guglielmo Marconi develop the wireless telegraph.

It was only over half a century later, in 1962, that a doctoral student of Curie's, Marguerite Perey, became the first woman elected to membership in the academy.

Despite Curie's fame as a scientist working for France, the public's attitude tended toward xenophobia—the same that had led to the Dreyfus affair—which also fuelled false speculation that Curie was Jewish.

During the French Academy of Sciences elections, she was vilified by the right-wing press as a foreigner and atheist. Her daughter later remarked on the French press's hypocrisy in portraying Curie as an unworthy foreigner when she was nominated for a French honour, but portraying her as a French heroine when she received foreign honours such as her Nobel Prizes.

In 1911 it was revealed that Curie was involved in a year-long affair with physicist Paul Langevin, a former student of Pierre Curie's, a married man who was estranged from his wife. This resulted in a press scandal that was exploited by her academic opponents.

Curie (then in her mid-40s) was five years older than Langevin and was misrepresented in the tabloids as a foreign Jewish home-wrecker.

When the scandal broke, she was away at a conference in Belgium; on her return, she found an angry mob in front of her house and had to seek refuge, with her daughters, in the home of her friend, Camille Marbo.

International recognition for her work had been growing to new heights, and the Royal Swedish Academy of Sciences, overcoming opposition prompted by the Langevin scandal, honoured her a second time, with the 1911 Nobel Prize in Chemistry.

This award was "in recognition of her services to the advancement of chemistry by the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature and compounds of this remarkable element." Because of the negative publicity due to her affair with Langevin, the chair of the Nobel committee, Svante Arrhenius, attempted to prevent her attendance at the official ceremony for her Nobel Prize in Chemistry, citing her questionable moral standing.

Curie replied that she would be present at the ceremony, because "the prize has been given to her for her discovery of polonium and radium" and that "there is no relation between her scientific work and the facts of her private life".

She was the first person to win or share two Nobel Prizes, and remains alone with Linus Pauling as Nobel laureates in two fields each. A delegation of celebrated Polish men of learning, headed by novelist Henryk Sienkiewicz, encouraged her to return to Poland and continue her research in her native country.

Curie's second Nobel Prize enabled her to persuade the French government to support the Radium Institute, built in 1914, where research was conducted in chemistry, physics, and medicine.

A month after accepting her 1911 Nobel Prize, she was hospitalised with depression and a kidney ailment. For most of 1912, she avoided public life but did spend time in England with her friend and fellow physicist, Hertha Ayrton. She returned to her laboratory only in December, after a break of about 14 months.

In 1912 the Warsaw Scientific Society offered her the directorship of a new laboratory in Warsaw but she declined, focusing on the developing Radium Institute to be completed in August 1914, and on a new street named Rue Pierre-Curie.

She was appointed Director of the Curie Laboratory in the Radium Institute of the University of Paris, founded in 1914. She visited Poland in 1913 and was welcomed in Warsaw but the visit was mostly ignored by the Russian authorities.

The institute's development was interrupted by the coming war, as most researchers were drafted into the French Army, and it fully resumed its activities in 1919.

World War I

During World War I, Curie recognised that wounded soldiers were best served if operated upon as soon as possible. She saw a need for field radiological centres near the front lines to assist battlefield surgeons, including to obviate amputations when in fact limbs could be saved.

After a quick study of radiology, anatomy, and automotive mechanics she procured X-ray equipment, vehicles, auxiliary generators, and developed mobile radiography units, which came to be popularly known as petites Curies (Little Curies).

She became the director of the Red Cross Radiology Service and set up France's first military radiology centre, operational by late 1914.

Assisted at first by a military doctor and her 17-year-old daughter Irène, Curie directed the installation of 20 mobile radiological vehicles and another 200 radiological units at field hospitals in the first year of the war. Later, she began training other women as aides.

In 1915, Curie produced hollow needles containing "radium emanation", a colourless, radioactive gas given off by radium, later identified as radon, to be used for sterilizing infected tissue. She provided the radium from her own one-gram supply. It is estimated that over a million wounded soldiers were treated with her X-ray units.

Busy with this work, she carried out very little scientific research during that period. In spite of all her humanitarian contributions to the French war effort, Curie never received any formal recognition of it from the French government.

Also, promptly after the war started, she attempted to donate her gold Nobel Prize medals to the war effort but the French National Bank refused to accept them. She did buy war bonds, using her Nobel Prize money.

She said: I am going to give up the little gold I possess. I shall add to this the scientific medals, which are quite useless to me. There is something else: by sheer laziness I had allowed the money for my second Nobel Prize to remain in Stockholm in Swedish crowns. This is the chief part of what we possess. I should like to bring it back here and invest it in war loans.

The state needs it. Only, I have no illusions: this money will probably be lost. She was also an active member in committees of Polonia in France dedicated to the Polish cause. After the war, she summarized her wartime experiences in a book, Radiology in War (1919).

Death

Curie visited Poland for the last time in early 1934.

A few months later, on 4 July 1934, she died aged 66 at the Sancellemoz sanatorium in Passy, Haute-Savoie, from aplastic anemia believed to have been contracted from her long-term exposure to radiation, causing damage to her bone marrow.

The damaging effects of ionising radiation were not known at the time of her work, which had been carried out without the safety measures later developed.

She had carried test tubes containing radioactive isotopes in her pocket, and she stored them in her desk drawer, remarking on the faint light that the substances gave off in the dark.

Curie was also exposed to X-rays from unshielded equipment while serving as a radiologist in field hospitals during the war.

In fact, when Curie's body was exhumed in 1995, the French Office de Protection contre les Rayonnements Ionisants (ORPI) "concluded that she could not have been exposed to lethal levels of radium while she was alive".

They pointed out that radium poses a risk only if it is ingested, and speculated that her illness was more likely to have been due to her use of radiography during the First World War.

She was interred at the cemetery in Sceaux, alongside her husband Pierre. Sixty years later, in 1995, in honour of their achievements, the remains of both were transferred to the Paris Panthéon.

Their remains were sealed in a lead lining because of the radioactivity. She became the second woman to be interred at the Panthéon (after Sophie Berthelot) and the first woman to be honoured with interment in the Panthéon on her own merits.

Because of their levels of radioactive contamination, her papers from the 1890s are considered too dangerous to handle. Even her cookbooks are highly radioactive.

Her papers are kept in lead-lined boxes, and those who wish to consult them must wear protective clothing. In her last year, she worked on a book, Radioactivity, which was published posthumously in 1935.

LegacyIf Curie's work helped overturn established ideas in physics and chemistry, it has had an equally profound effect in the societal sphere. To attain her scientific achievements, she had to overcome barriers, in both her native and her adoptive country, that were placed in her way because she was a woman.

This aspect of her life and career is highlighted in Françoise Giroud's Marie Curie: A Life, which emphasizes Curie's role as a feminist precursor.

She was known for her honesty and moderate lifestyle. Having received a small scholarship in 1893, she returned it in 1897 as soon as she began earning her keep.

She gave much of her first Nobel Prize money to friends, family, students, and research associates. In an unusual decision, Curie intentionally refrained from patenting the radium-isolation process so that the scientific community could do research unhindered.

She insisted that monetary gifts and awards be given to the scientific institutions she was affiliated with rather than to her.

She and her husband often refused awards and medals. Albert Einstein reportedly remarked that she was probably the only person who could not be corrupted by fame.

The physical and societal aspects of the Curies' work contributed to shaping the world of the twentieth and twenty-first centuries. Cornell University Professor L. Pearce Williams observes:

The result of the Curies' work was epoch-making. Radium's radioactivity was so great that it could not be ignored. It seemed to contradict the principle of the conservation of energy and therefore forced a reconsideration of the foundations of physics.

On the experimental level the discovery of radium provided men like Ernest Rutherford with sources of radioactivity with which they could probe the structure of the atom.

As a result of Rutherford's experiments with alpha radiation, the nuclear atom was first postulated.

In medicine, the radioactivity of radium appeared to offer a means by which cancer could be successfully attacked.

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Honours and tributes

As one of the most famous scientists in history, Marie Curie has become an icon in the scientific world and has received tributes from across the globe, even in the realm of pop culture.

In 1995, she became the first woman to be entombed on her own merits in the Panthéon, Paris.

In a 2009 poll carried out by New Scientist, she was voted the "most inspirational woman in science". Curie received 25.1 percent of all votes cast, nearly twice as many as second-place Rosalind Franklin (14.2 per cent).

On the centenary of her second Nobel Prize, Poland declared 2011 the Year of Marie Curie; and the United Nations declared that this would be the International Year of Chemistry. An artistic installation celebrating "Madame Curie" filled the Jacobs Gallery at San Diego's Museum of Contemporary Art.

On 7 November, Google celebrated the anniversary of her birth with a special Google Doodle. On 10 December, the New York Academy of Sciences celebrated the centenary of Marie Curie's second Nobel Prize in the presence of Princess Madeleine of Sweden.

Marie Curie was the first woman to win a Nobel Prize, the first person to win two Nobel Prizes, the only woman to win in two fields, and the only person to win in multiple sciences. Awards that she received include:

Nobel Prize in Physics (1903, with her husband Pierre Curie and Henri Becquerel).

Davy Medal (1903, with Pierre).

Matteucci Medal (1904, with Pierre).

Actonian Prize (1907).

Elliott Cresson Medal (1909).

Nobel Prize in Chemistry (1911).

Franklin Medal of the American Philosophical Society (1921).

She received numerous honorary degrees from universities across the world.

In Poland, she received honorary doctorates from the Lwów Polytechnic (1912), Poznań University (1922), Kraków's Jagiellonian University (1924), and the Warsaw Polytechnic (1926).

In 1920 she became the first female member of The Royal Danish Academy of Sciences and Letters. In 1921, in the U.S., she was awarded membership in the Iota Sigma Pi women scientists' society.

In 1924, she became an Honorary Member of the Polish Chemical Society. Marie Curie's 1898 publication with her husband and their collaborator Gustave Bémont of their discovery of radium and polonium was honoured by a Citation for Chemical Breakthrough Award from the Division of History of Chemistry of the American Chemical Society presented to the ESPCI Paris in 2015.

Entities that have been named in her honour include:

The curie, a unit of radioactivity, is named in honour of her and Pierre Curie (although the commission which agreed on the name never clearly stated whether the standard was named after Pierre, Marie, or both).

The element with atomic number 96 was named curium (symbol Cm).

Three radioactive minerals are also named after the Curies: curite, sklodowskite, and cuprosklodowskite.

The Marie Skłodowska-Curie Actions fellowship program of the European Union for young scientists wishing to work in a foreign country is named after her.

In 2007, a metro station in Paris was renamed to honour both of the Curies.

The sole Polish nuclear reactor in operation, the research reactor Maria, is named after her.

The 7000 Curie asteroid is also named after her.

A KLM McDonnell Douglas MD-11 (registration PH-KCC) is named in her honour.

In 2011, a new Warsaw bridge over the Vistula River was named in her honour.

In January 2020, Satellogic, a high-resolution Earth observation imaging and analytics company, launched a ÑuSat type micro-satellite; ÑuSat 8, also known as Marie, was named in her honour.

The Marie-Curie station, a planned underground Réseau express métropolitain (REM) station in the borough of Saint-Laurent in Montreal is named in her honour. A nearby road, Avenue Marie Curie, is also named in her honour.

The molecular docking task CurieMariedock is a component of the Slovenian distributed computing project SiDock (which runs under the aegis of BOINC); its focus is SARS-CoV-2.

Mount Curie in New Zealand's Paparoa Range was named after her in 1970 by the Department of Scientific and Industrial Research.

The Marie Curie Medal, an annual science award established in 1996 and conferred by the Polish Chemical Society was named after her.

The Marie Curie-Sklodowska Medal and Prize, an annual award conferred by the London-based Institute of Physics for distinguished contributions to physics education was named in her honour.

Several institutions presently bear her name, including the two Curie institutes which she founded: The Maria Sklodowska-Curie National Research Institute of Oncology in Warsaw, and the Institut Curie in Paris.

The Maria Curie-Skłodowska University, in Lublin, was founded in 1944; and the Pierre and Marie Curie University (also known as Paris VI) was France's pre-eminent science university, which would later merge to form the Sorbonne University. In Britain, the Marie Curie charity was organized in 1948 to care for the terminally ill. Two museums are devoted to Marie Curie.

In 1967, the Maria Skłodowska-Curie Museum was established in Warsaw's "New Town", at her birthplace on ulica Freta (Freta Street). Her Paris laboratory is preserved as the Musée Curie, open since 1992. Curie's likeness has appeared on banknotes, stamps and coins around the world.

She was featured on the Polish late-1980s 20,000-złoty banknote as well as on the last French 500-franc note, before the franc was replaced by the euro. Curie-themed postage stamps from Mali, the Republic of Togo, Zambia, and the Republic of Guinea actually show a picture of Susan Marie Frontczak portraying Curie in a 2001 picture by Paul Schroeder.

Her likeness or name has appeared on several artistic works. In 1935, Michalina Mościcka, wife of Polish President Ignacy Mościcki, unveiled a statue of Marie Curie before Warsaw's Radium Institute; during the 1944 Second World War Warsaw Uprising against the Nazi German occupation, the monument was damaged by gunfire; after the war it was decided to leave the bullet marks on the statue and its pedestal.

About Stephen Hawking

Stephen William Hawking (8 January 1942 – 14 March 2018) was an English theoretical physicist, cosmologist, and author who, at the time of his death, was director of research at the Centre for Theoretical Cosmology at the University of Cambridge.

Between 1979 and 2009, he was the Lucasian Professor of Mathematics at the University of Cambridge, widely viewed as one of the most prestigious academic posts in the world.

Hawking was born in Oxford into a family of physicians. In October 1959, at the age of 17, he began his university education at University College, Oxford, where he received a first-class BA degree in physics.

In October 1962, he began his graduate work at Trinity Hall at the University of Cambridge where, in March 1966, he obtained his PhD degree in applied mathematics and theoretical physics, specializing in general relativity and cosmology.

In 1963, at age 21, Hawking was diagnosed with an early-onset slow-progressing form of motor neurone disease that gradually, over decades, paralysed him.

After the loss of his speech, he communicated through a speech-generating device initially through use of a handheld switch, and eventually by using a single cheek muscle.

Hawking's scientific works included a collaboration with Roger Penrose on gravitational singularity theorems in the framework of general relativity, and the theoretical prediction that black holes emit radiation, often called Hawking radiation.

Initially, hawking radiation was controversial. By the late 1970s and following the publication of further research, the discovery was widely accepted as a major breakthrough in theoretical physics.

Hawking was the first to set out a theory of cosmology explained by a union of the general theory of relativity and quantum mechanics. He was a vigorous supporter of the many-worlds interpretation of quantum mechanics.

Hawking achieved commercial success with several works of popular science in which he discussed his theories and cosmology in general. His book A Brief History of Time appeared on the Sunday Times best-seller list for a record-breaking 237 weeks.

Hawking was a Fellow of the Royal Society, a lifetime member of the Pontifical Academy of Sciences, and a recipient of the Presidential Medal of Freedom, the highest civilian award in the United States.

In 2002, Hawking was ranked number 25 in the BBC's poll of the 100 Greatest Britons. He died in 2018 at the age of 76, after living with motor neurone disease for more than 50 years.

Early life

Hawking was born on 8 January 1942 in Oxford to Frank and Isobel Eileen Hawking. Hawking's mother was born into a family of doctors in Glasgow, Scotland.

His wealthy paternal great-grandfather, from Yorkshire, over-extended himself buying farm land and then went bankrupt in the great agricultural depression during the early 20th century. His paternal great-grandmother saved the family from financial ruin by opening a school in their home.

Despite their families' financial constraints, both parents attended the University of Oxford, where Frank read medicine and Isobel read Philosophy, Politics and Economics. Isobel worked as a secretary for a medical research institute, and Frank was a medical researcher.

Hawking had two younger sisters, Philippa and Mary, and an adopted brother, Edward Frank David (1955–2003).

In 1950, when Hawking's father became head of the division of parasitology at the National Institute for Medical Research, the family moved to St Albans, Hertfordshire.

In St Albans, the family was considered highly intelligent and somewhat eccentric; meals were often spent with each person silently reading a book.

They lived a frugal existence in a large, cluttered, and poorly maintained house and travelled in a converted London taxicab.

During one of Hawking's father's frequent absences working in Africa, the rest of the family spent four months in Mallorca

visiting his mother's friend Beryl and her husband, the poet Robert Graves.

Primary and secondary school years

Hawking began his schooling at the Byron House School in Highgate, London. He later blamed its "progressive methods" for his failure to learn to read while at the school. In St Albans, the eight-year-old Hawking attended St Albans High School for Girls for a few months. At that time, younger boys could attend one of the houses.

Hawking attended two private (i.e. fee-paying) schools, first Radlett School and from September 1952, St Albans School, Hertfordshire, after passing the eleven-plus a year early. The family placed a high value on education.

Hawking's father wanted his son to attend Westminster School, but the 13-year-old Hawking was ill on the day of the scholarship examination. His family could not afford the school fees without the financial aid of a scholarship, so Hawking remained at St Albans.

A positive consequence was that Hawking remained close to a group of friends with whom he enjoyed board games, the manufacture of fireworks, model aeroplanes and boats, and long discussions about Christianity and extrasensory perception.

From 1958 on, with the help of the mathematics teacher Dikran Tahta, they built a computer from clock parts, an old telephone switchboard and other recycled components.

Although known at school as "Einstein", Hawking was not initially successful academically. With time, he began to show considerable aptitude for scientific subjects and, inspired by Tahta, decided to read mathematics at university.

Hawking's father advised him to study medicine, concerned that there were few jobs for mathematics graduates. He also wanted his son to attend University College, Oxford, his own alma mater.

As it was not possible to read mathematics there at the time, Hawking decided to study physics and chemistry. Despite his headmaster's advice to wait until the next year, Hawking was awarded a scholarship after taking the examinations in March 1959.

Undergraduate years

Hawking began his university education at University College, Oxford, in October 1959 at the age of 17. For the first eighteen months, he was bored and lonely – he found the academic work "ridiculously easy".

His physics tutor, Robert Berman, later said, "It was only necessary for him to know that something could be done, and he could do it without looking to see how other people did it." A change occurred during his second and third years when, according to Berman, Hawking made more of an effort "to be one of the boys".

He developed into a popular, lively and witty college-member, interested in classical music and science fiction.

Part of the transformation resulted from his decision to join the college boat-club, the University College Boat Club, where he coxed a rowing-crew.

The rowing-coach at the time noted that Hawking cultivated a daredevil image, steering his crew on risky courses that led to damaged boats. Hawking estimated that he studied about 1,000 hours during his three years at Oxford.

These unimpressive study habits made sitting his finals a challenge, and he decided to answer only theoretical physics questions rather than those requiring factual knowledge.

A first-class degree was a condition of acceptance for his planned graduate study in cosmology at the University of Cambridge.

Anxious, he slept poorly the night before the examinations, and the result was on the borderline between first- and second-class honours, making a viva (oral examination) with the Oxford examiners necessary.

Hawking was concerned that he was viewed as a lazy and difficult student.

So, when asked at the viva to describe his plans, he said, "If you award me a First, I will go to Cambridge. If I receive a Second, I shall stay in Oxford, so I expect you will give me a First."

He was held in higher regard than he believed; as Berman commented, the examiners "were intelligent enough to realise they were talking to someone far cleverer than most of themselves".

After receiving a first-class BA degree in physics and completing a trip to Iran with a friend, he began his graduate work at Trinity Hall, Cambridge, in October 1962.

Post-graduate years

Hawking's first year as a doctoral student was difficult. He was initially disappointed to find that he had been assigned Dennis William Sciama, one of the founders of modern cosmology, as a supervisor rather than the noted astronomer Fred Hoyle, and he found his training in mathematics inadequate for work in general relativity and cosmology.

After being diagnosed with motor neurone disease, Hawking fell into a depression – though his doctors advised that he continue with his studies, he felt there was little point. His disease progressed more slowly than doctors had predicted. Although Hawking had difficulty walking unsupported, and his speech was almost unintelligible, an initial diagnosis that he had only two years to live proved unfounded.

With Sciama's encouragement, he returned to his work. Hawking started developing a reputation for brilliance and brashness when he publicly challenged the work of Fred Hoyle and his student Jayant Narlikar at a lecture in June 1964.

When Hawking began his doctoral studies, there was much debate in the physics community about the prevailing theories of the creation of the universe: The Big Bang and Steady State theories. Inspired by Roger Penrose's theorem of a spacetime singularity in the centre of black holes, Hawking applied the same thinking to the entire universe; and, during 1965, he wrote his thesis on this topic.

Hawking's thesis was approved in 1966.

There were other positive developments: Hawking received a research fellowship at Gonville and Caius College at Cambridge; he obtained his PhD degree in applied mathematics and theoretical physics, specializing in general relativity and cosmology, in March 1966; and his essay "Singularities and the Geometry of Space–Time" shared top honours with one by Penrose to win that year's prestigious Adams Prize.

Career, 1966–1975

In his work, and in collaboration with Penrose, Hawking extended the singularity theorem concepts first explored in his doctoral thesis. This included not only the existence of singularities but also the theory that the universe might have started as a singularity.

Their joint essay was the runner-up in the 1968 Gravity Research Foundation competition. In 1970, they published a proof that if the universe obeys the general theory of relativity and fits any of the models of physical cosmology developed by Alexander Friedmann, then it must have begun as a singularity.

In 1969, Hawking accepted a specially created Fellowship for Distinction in Science to remain at Caius. In 1970, Hawking postulated what became known as the second law of black hole dynamics, that the event horizon of a black hole can never get smaller.

With James M. Bardeen and Brandon Carter, he proposed the four laws of black hole mechanics, drawing an analogy with thermodynamics To Hawking's irritation, Jacob Bekenstein, a

graduate student of John Wheeler, went further—and ultimately correctly—to apply thermodynamic concepts literally.

In the early 1970s, Hawking's work with Carter, Werner Israel, and David C. Robinson strongly supported Wheeler's no-hair theorem, one that states that no matter what the original material from which a black hole is created, it can be completely described by the properties of mass, electrical charge and rotation.

His essay titled "Black Holes" won the Gravity Research Foundation Award in January 1971.

Hawking's first book, The Large Scale Structure of Space-Time, written with George Ellis, was published in 1973.

Beginning in 1973, Hawking moved into the study of quantum gravity and quantum mechanics.

His work in this area was spurred by a visit to Moscow and discussions with Yakov Borisovich Zel'dovich and Alexei Starobinsky, whose work showed that according to the uncertainty principle, rotating black holes emit particles.

To Hawking's annoyance, his much-checked calculations produced findings that contradicted his second law, which claimed black holes could never get smaller, and supported Bekenstein's reasoning about their entropy.

His results, which Hawking presented from 1974, showed that black holes emit radiation, known today as Hawking radiation, which may continue until they exhaust their energy and evaporate.

Initially, Hawking radiation was controversial. By the late 1970s and following the publication of further research, the discovery was widely accepted as a significant breakthrough in theoretical physics. Hawking was elected a Fellow of the Royal Society (FRS) in 1974, a few weeks after the announcement of Hawking radiation. At the time, he was one of the youngest scientists to become a Fellow.

Hawking was appointed to the Sherman Fairchild Distinguished Visiting Professorship at the California Institute of Technology (Caltech) in 1974. He worked with a friend on the faculty, Kip Thorne, and engaged him in a scientific wager about whether the X-ray source Cygnus X-1 was a black hole.

The wager was an "insurance policy" against the proposition that black holes did not exist. Hawking acknowledged that he had lost the bet in 1990, a bet that was the first of several he was to make with Thorne and others. Hawking had maintained ties to Caltech, spending a month there almost every year since this first visit.

1975–1990

Hawking returned to Cambridge in 1975 to a more academically senior post, as reader in gravitational physics. The mid-to-late 1970s were a period of growing public interest in black holes and the physicists who were studying them.

Hawking was regularly interviewed for print and television. He also received increasing academic recognition of his work. In 1975, he was awarded both the Eddington Medal and the Pius XI Gold Medal, and in 1976 the Dannie Heineman Prize, the Maxwell Medal and Prize and the Hughes Medal.

He was appointed a professor with a chair in gravitational physics in 1977. The following year he received the Albert Einstein Medal and an honorary doctorate from the University of Oxford.

In 1979, Hawking was elected Lucasian Professor of Mathematics at the University of Cambridge. His inaugural lecture in this role was titled: "Is the End in Sight for Theoretical Physics?" and proposed N = 8 supergravity as the leading theory to solve many of the outstanding problems physicists were studying.

His promotion coincided with a health-crisis which led to his accepting, albeit reluctantly, some nursing services at home. At the same time, he was also making a transition in his approach to physics, becoming more intuitive and speculative rather than insisting on mathematical proofs. "I would rather be right than rigorous", he told Kip Thorne.

In 1981, he proposed that information in a black hole is irretrievably lost when a black hole evaporates. This information paradox violates the fundamental tenet of quantum mechanics, and led to years of debate, including "the Black Hole War" with Leonard Susskind and Gerard 't Hooft.

Cosmological inflation – a theory proposing that following the Big Bang, the universe initially expanded incredibly rapidly before settling down to a slower expansion – was proposed by Alan Guth and also developed by Andrei Linde.

Following a conference in Moscow in October 1981, Hawking and Gary Gibbons organized a three-week Nuffield Workshop in the summer of 1982 on "The Very Early Universe" at Cambridge

University, a workshop that focused mainly on inflation theory. Hawking also began a new line of quantum-theory research into the origin of the universe.

In 1981 at a Vatican conference, he presented work suggesting that there might be no boundary – or beginning or ending – to the universe.

Hawking subsequently developed the research in collaboration with Jim Hartle, and in 1983 they published a model, known as the Hartle–Hawking state. It proposed that prior to the Planck epoch, the universe had no boundary in space-time; before the Big Bang, time did not exist and the concept of the beginning of the universe is meaningless.

The initial singularity of the classical Big Bang models was replaced with a region akin to the North Pole. One cannot travel north of the North Pole, but there is no boundary there – it is simply the point where all north-running lines meet and end. Initially, the no-boundary proposal predicted a closed universe, which had implications about the existence of God.

As Hawking explained, "If the universe has no boundaries but is self-contained... then God would not have had any freedom to choose how the universe began."

Hawking did not rule out the existence of a Creator, asking in A Brief History of Time "Is the unified theory so compelling that it brings about its own existence?", also stating "If we discover a complete theory, it would be the ultimate triumph of human reason – for then we should know the mind of God"; in his early work, Hawking spoke of God in a metaphorical sense. In the

same book he suggested that the existence of God was not necessary to explain the origin of the universe.

Later discussions with Neil Turok led to the realization that the existence of God was also compatible with an open universe.

Further work by Hawking in the area of arrows of time led to the 1985 publication of a paper theorizing that if the no-boundary proposition were correct, then when the universe stopped expanding and eventually collapsed, time would run backwards.

A paper by Don Page and independent calculations by Raymond Laflamme led Hawking to withdraw this concept. Honours continued to be awarded: in 1981 he was awarded the American Franklin Medal, and in the 1982 New Year Honors appointed a Commander of the Order of the British Empire (CBE).

These awards did not significantly change Hawking's financial status, and motivated by the need to finance his children's education and home-expenses, he decided in 1982 to write a popular book about the universe that would be accessible to the general public.

Instead of publishing with an academic press, he signed a contract with Bantam Books, a mass-market publisher, and received a large advance for his book. A first draft of the book, called A Brief History of Time, was completed in 1984.

One of the first messages Hawking produced with his speech-generating device was a request for his assistant to help him finish writing A Brief History of Time.

Peter Guzzardi, his editor at Bantam, pushed him to explain his ideas clearly in non-technical language, a process that required many revisions from an increasingly irritated Hawking. The book was published in April 1988 in the US and in June in the UK, and it proved to be an extraordinary success, rising quickly to the top of best-seller lists in both countries and remaining there for months.

The book was translated into many languages, and as of 2009, has sold an estimated 9 million copies.

Media attention was intense, and a Newsweek magazine-cover and a television special both described him as "Master of the Universe". Success led to significant financial rewards, but also the challenges of celebrity status.

Hawking travelled extensively to promote his work, and enjoyed partying and dancing into the small hours. A difficulty refusing the invitations and visitors left him limited time for work and his students. Some colleagues were resentful of the attention Hawking received, feeling it was due to his disability.

He received further academic recognition, including five more honorary degrees, the Gold Medal of the Royal Astronomical Society (1985), the Paul Dirac Medal (1987) and, jointly with Penrose, the prestigious Wolf Prize (1988).

In the 1989 Birthday Honors, he was appointed a Companion of Honor (CH). He reportedly declined a knighthood in the late 1990s in objection to the UK's science funding policy.

Hawking pursued his work in physics: in 1993 he co-edited a book on Euclidean quantum gravity with Gary Gibbons and

published a collected edition of his own articles on black holes and the Big Bang. In 1994, at Cambridge's Newton Institute, Hawking and Penrose delivered a series of six lectures that were published in 1996 as "The Nature of Space and Time".

In 1997, he conceded a 1991 public scientific wager made with Kip Thorne and John Preskill of Caltech. Hawking had bet that Penrose's proposal of a "cosmic censorship conjecture" – that there could be no "naked singularities" unclothed within a horizon – was correct.

After discovering his concession might have been premature, a new and more refined wager was made. This one specified that such singularities would occur without extra conditions. The same year, Thorne, Hawking and Preskill made another bet, this time concerning the black hole information paradox.

Thorne and Hawking argued that since general relativity made it impossible for black holes to radiate and lose information, the mass-energy and information carried by Hawking radiation must be "new", and not from inside the black hole event horizon.

Since this contradicted the quantum mechanics of microcausality, quantum mechanics theory would need to be rewritten. Preskill argued the opposite, that since quantum mechanics suggests that the information emitted by a black hole relates to information that fell in at an earlier time, the concept of black holes given by general relativity must be modified in some way.

Hawking also maintained his public profile, including bringing science to a wider audience.

A film version of A Brief History of Time, directed by Errol Morris and produced by Steven Spielberg, premiered in 1992. Hawking had wanted the film to be scientific rather than biographical, but he was persuaded otherwise.

The film, while a critical success, was not widely released. A popular-level collection of essays, interviews, and talks titled Black Holes and Baby Universes and Other Essays was published in 1993, and a six-part television series Stephen Hawking's Universe and a companion book appeared in 1997.

As Hawking insisted, this time the focus was entirely on science.

Hawking continued his writings for a popular audience, publishing The Universe in a Nutshell in 2001, and A Briefer History of Time, which he wrote in 2005 with Leonard Mlodinow to update his earlier works with the aim of making them accessible to a wider audience, and God Created the Integers, which appeared in 2006.

Along with Thomas Hertog at CERN and Jim Hartle, from 2006 on Hawking developed a theory of top-down cosmology, which says that the universe had not one unique initial state but many different ones, and therefore that it is inappropriate to formulate a theory that predicts the universe's current configuration from one particular initial state.

Top-down cosmology posits that the present "selects" the past from a superposition of many possible histories. In doing so, the theory suggests a possible resolution of the fine-tuning question.

Hawking continued to travel widely, including trips to Chile, Easter Island, South Africa, Spain (to receive the Fonseca Prize in 2008), Canada, and numerous trips to the United States.

For practical reasons related to his disability, Hawking increasingly travelled by private jet, and by 2011 that had become his only mode of international travel. By 2003, consensus among physicists was growing that Hawking was wrong about the loss of information in a black hole.

In a 2004 lecture in Dublin, he conceded his 1997 bet with Preskill, but described his own, somewhat controversial solution to the information paradox problem, involving the possibility that black holes have more than one topology.

In the 2005 paper he published on the subject, he argued that the information paradox was explained by examining all the alternative histories of universes, with the information loss in those with black holes being cancelled out by those without such loss.

In January 2014, he called the alleged loss of information in black holes his "biggest blunder".

As part of another longstanding scientific dispute, Hawking had emphatically argued, and bet, that the Higgs boson would never be found. The particle was proposed to exist as part of the Higgs field theory by Peter Higgs in 1964.

Hawking and Higgs engaged in a heated and public debate over the matter in 2002 and again in 2008, with Higgs criticizing Hawking's work and complaining that Hawking's "celebrity status gives him instant credibility that others do not have."

The particle was discovered in July 2012 at CERN following construction of the Large Hadron Collider. Hawking quickly conceded that he had lost his bet and said that Higgs should win the Nobel Prize for Physics, which he did in 2013.

In 2007, Hawking and his daughter Lucy published George's Secret Key to the Universe, a children's book designed to explain theoretical physics in an accessible fashion and featuring characters similar to those in the Hawking family.

The book was followed by sequels in 2009, 2011, 2014 and 2016. In 2002, following a UK-wide vote, the BBC included Hawking in their list of the 100 Greatest Britons. He was awarded the Copley Medal from the Royal Society (2006), the Presidential Medal of Freedom, which is America's highest civilian honour (2009), and the Russian Special Fundamental Physics Prize (2013).

Several buildings have been named after him, including the Stephen W.

Hawking Science Museum in San Salvador, El Salvador, the Stephen Hawking Building in Cambridge, and the Stephen Hawking Centre at the Perimeter Institute in Canada. Appropriately, given Hawking's association with time, he unveiled the mechanical "Chronophage" (or time-eating) Corpus Clock at Corpus Christi College, Cambridge in September 2008.

During his career, Hawking supervised 39 successful PhD students. One doctoral student did not successfully complete the PhD. better source needed.

As required by Cambridge University policy, Hawking retired as Lucasian Professor of Mathematics in 2009. Despite suggestions that he might leave the United Kingdom as a protest against public funding cuts to basic scientific research, Hawking worked as director of research at the Cambridge University Department of Applied Mathematics and Theoretical Physics.

On 28 June 2009, as a tongue-in-cheek test of his 1992 conjecture that travel into the past is effectively impossible, Hawking held a party open to all, complete with hors d'oeuvres and iced champagne, but publicized the party only after it was over so that only time-travellers would know to attend; as expected, nobody showed up to the party.

On 20 July 2015, Hawking helped launch Breakthrough Initiatives, an effort to search for extraterrestrial life. Hawking created Stephen Hawking: Expedition New Earth, a documentary on space colonization, as a 2017 episode of Tomorrow's World.

In August 2015, Hawking said that not all information is lost when something enters a black hole and there might be a possibility to retrieve information from a black hole according to his theory.

In July 2017, Hawking was awarded an Honorary Doctorate from Imperial College London.

Hawking's final paper – A smooth exit from eternal inflation? – was posthumously published in the Journal of High Energy Physics on 27 April 2018.

Death

Hawking died at his home in Cambridge on 14 March 2018, at the age of 76. His family stated that he "died peacefully". He was eulogized by figures in science, entertainment, politics, and other areas.

The Gonville and Caius College flag flew at half-mast and a book of condolences was signed by students and visitors. A tribute was made to Hawking in the closing speech by IPC President Andrew Parsons at the closing ceremony of the 2018 Paralympic Winter Games in Pyeongchang, South Korea.

His private funeral took place on 31 March 2018, at Great St Mary's Church, Cambridge. Guests at the funeral included The Theory of Everything actors Eddie Redmayne and Felicity Jones, Queen guitarist and astrophysicist Brian May, and model Lily Cole.

In addition, actor Benedict Cumberbatch, who played Stephen Hawking in Hawking, astronaut Tim Peake, Astronomer Royal Martin Rees and physicist Kip Thorne provided readings at the service. Although Hawking was an atheist, the funeral took place with a traditional Anglican service.

Following the cremation, a service of thanksgiving was held at Westminster Abbey on 15 June 2018, after which his ashes were interred in the Abbey's nave, between the graves of Sir Isaac Newton and Charles Darwin.

Inscribed on his memorial stone are the words "Here lies what was mortal of Stephen Hawking 1942–2018" and his most famed equation.

He directed, at least fifteen years before his death, that the Bekenstein–Hawking entropy equation be his epitaph.

In June 2018, it was announced that Hawking's words, set to music by Greek composer Vangelis, would be beamed into space from a European space agency satellite dish in Spain with the aim of reaching the nearest black hole, 1A 0620-00.

Hawking's final broadcast interview, about the detection of gravitational waves resulting from the collision of two neutron stars, occurred in October 2017.

His final words to the world appeared posthumously, in April 2018, in the form of a Smithsonian TV Channel documentary entitled, Leaving Earth: Or How to Colonize a Planet.

One of his final research studies, entitled A smooth exit from eternal inflation?, about the origin of the universe, was published in the Journal of High Energy Physics in May 2018. Later, in October 2018, another of his final research studies, entitled Black Hole Entropy and Soft Hair, was published, and dealt with the "mystery of what happens to the information held by objects once they disappear into a black hole".

Also in October 2018, Hawking's last book, Brief Answers to the Big Questions, a popular science book presenting his final comments on the most important questions facing humankind, was published.

On 8 November 2018, an auction of 22 personal possessions of Stephen Hawking, including his doctoral thesis ("Properties of Expanding Universes", PhD thesis, Cambridge University, 1965) and wheelchair, took place, and fetched about £1.8 m.

Proceeds from the auction sale of the wheelchair went to two charities, the Motor Neurone Disease Association and the Stephen Hawking Foundation; proceeds from Hawking's other items went to his estate.

In March 2019, it was announced that the Royal Mint would issue a commemorative 50p coin, only available as a commemorative edition, in honour of Hawking. The same month, Hawking's nurse, Patricia Dowdy, was struck off the nursing register for "failures over his care and financial misconduct."

In May 2021 it was announced that an Acceptance-in-Lieu agreement between HMRC, the Department for Culture, Media and Sport, Cambridge University Library, Science Museum Group, and the Hawking Estate, would see around 10,000 pages of Hawking's scientific and other papers remain in Cambridge, while objects including his wheelchairs, speech synthesisers, and personal memorabilia from his former Cambridge office would be housed at the Science Museum.

In February 2022 the "Stephen Hawking at Work" display opened at the Science Museum, London as the start of a two-year nationwide tour.

Awards and honours

Hawking received numerous awards and honours. Already early in the list, in 1974 he was elected a Fellow of the Royal Society (FRS). At that time, his nomination read:

Hawking has made major contributions to the field of general relativity.

These derive from a deep understanding of what is relevant to physics and astronomy, and especially from a mastery of wholly new mathematical techniques.

Following the pioneering work of Penrose, he established, partly alone and partly in collaboration with Penrose, a series of successively stronger theorems establishing the fundamental result that all realistic cosmological models must possess singularities.

Using similar techniques, Hawking has proved the basic theorems on the laws governing black holes: that stationary solutions of Einstein's equations with smooth event horizons must necessarily be axisymmetric; and that in the evolution and interaction of black holes, the total surface area of the event horizons must increase.

In collaboration with G. Ellis, Hawking is the author of an impressive and original treatise on "Space-time in the Large".

The citation continues, "Other important work by Hawking relates to the interpretation of cosmological observations and to the design of gravitational wave detectors."

Hawking was also a member of the American Academy of Arts and Sciences (1984), the American Philosophical Society (1984), and the United States National Academy of Sciences (1992).

Hawking received the 2015 BBVA Foundation Frontiers of Knowledge Award in Basic Sciences shared with Viatcheslav Mukhanov for discovering that the galaxies were formed from quantum fluctuations in the early Universe.

At the 2016 Pride of Britain Awards, Hawking received the lifetime achievement award "for his contribution to science and British culture". After receiving the award from Prime Minister Theresa May, hawking humorously requested that she not seek his help with Brexit.

Medal for Science Communication

Main article: Stephen Hawking Medal for Science Communication

Hawking was a member of the advisory board of the Starmus Festival, and had a major role in acknowledging and promoting science communication. The Stephen Hawking Medal for Science Communication is an annual award initiated in 2016 to honor members of the arts community for contributions that help build awareness of science.

Recipients receive a medal bearing a portrait of Hawking by Alexei Leonov, and the other side represents an image of Leonov himself performing the first spacewalk along with an image of the "Red Special", the guitar of Queen musician and astrophysicist Brian May (with music being another major component of the Starmus Festival).

The Starmus III Festival in 2016 was a tribute to Stephen Hawking and the book of all Starmus III lectures, "Beyond the Horizon", was also dedicated to him. The first recipients of the medals, which were awarded at the festival, were chosen by Hawking himself.

They were composer Hans Zimmer, physicist Jim Al-Khalili, and the science documentary Particle Fever.

Popular books:

A Brief History of Time (1988).

Black Holes and Baby Universes and Other Essays (1993).

The Universe in a Nutshell (2001).

On the Shoulders of Giants (2002).

God Created the Integers: The Mathematical Breakthroughs That Changed History (2005).

The Dreams That Stuff Is Made of: The Most Astounding Papers of Quantum Physics and How They Shook the Scientific World (2011).

My Brief History (2013) Hawking's memoir.

Brief Answers to the Big Questions (2018).

Co-authored:

The Nature of Space and Time (with Roger Penrose) (1996).

The Large, the Small and the Human Mind (with Roger Penrose, Abner Shimony and Nancy Cartwright) (1997).

The Future of Spacetime (with Kip Thorne, Igor Novikov, Timothy Ferris and introduction by Alan Lightman, Richard H. Price) (2002).

A Briefer History of Time (with Leonard Mlodinow) (2005).

The Grand Design (with Leonard Mlodinow) (2010).

Forewords:

Black Holes & Time Warps: Einstein's Outrageous Legacy (Kip Thorne, and introduction by Frederick Seitz) (1994).

The Physics of Star Trek (Lawrence Krauss) (1995).

About James Clerk Maxwell

James Clerk Maxwell FRSE FRS (13 June 1831 – 5 November 1879) was a Scottish mathematician and scientist responsible for the classical theory of electromagnetic radiation, which was the first theory to describe electricity, magnetism and light as different manifestations of the same phenomenon.

Maxwell's equations for electromagnetism have been called the "second great unification in physics" where the first one had been realised by Isaac Newton.

With the publication of "A Dynamical Theory of the Electromagnetic Field" in 1865, Maxwell demonstrated that electric and magnetic fields travel through space as waves moving at the speed of light. He proposed that light is an undulation in the same medium that is the cause of electric and magnetic phenomena.

The unification of light and electrical phenomena led to his prediction of the existence of radio waves. Maxwell is also regarded as a founder of the modern field of electrical engineering.

Maxwell helped develop the Maxwell–Boltzmann distribution, a statistical means of describing aspects of the kinetic theory of gases.

He is also known for presenting the first durable color photograph in 1861 and for his foundational work on analyzing the rigidity of rod-and-joint frameworks (trusses) like those in many bridges.

His discoveries helped usher in the era of modern physics, laying the foundation for such fields as special relativity and quantum mechanics.

Many physicists regard Maxwell as the 19th-century scientist having the greatest influence on 20th-century physics. His contributions to the science are considered by many to be of the same magnitude as those of Isaac Newton and Albert Einstein.

In the millennium poll—a survey of the 100 most prominent physicists—Maxwell was voted the third greatest physicist of all time, behind only Newton and Einstein. On the centenary of Maxwell's birthday, Einstein described Maxwell's work as the "most profound and the most fruitful that physics has experienced since the time of Newton".

Einstein, when he visited the University of Cambridge in 1922, was told by his host that he had done great things because he stood on Newton's shoulders; Einstein replied: "No I don't. I stand on the shoulders of Maxwell".

Early life, 1831–1839

Clerk Maxwell's birthplace at 14 India Street in Edinburgh is now the home of the James Clerk Maxwell Foundation.

James Clerk Maxwell was born on 13 June 1831 at 14 India Street, Edinburgh, to John Clerk Maxwell of Middlebie, an advocate, and Frances Cay, daughter of Robert Hodshon Cay and sister of John Cay.

（His birthplace now houses a museum operated by the James Clerk Maxwell Foundation）

His father was a man of comfortable means of the Clerk family of Penicuik, holders of the baronetcy of Clerk of Penicuik. His father's brother was the 6th baronet. He had been born "John Clerk", adding "Maxwell" to his own after he inherited (as an infant in 1793) the Middlebie estate, a Maxwell property in Dumfriesshire.

James was a first cousin of both the artist Jemima Blackburn (the daughter of his father's sister) and the civil engineer William Dyce Cay (the son of his mother's brother). Cay and Maxwell were close friends and Cay acted as his best man when Maxwell married.

Maxwell's parents met and married when they were well into their thirties; his mother was nearly 40 when he was born. They had had one earlier child, a daughter named Elizabeth, who died in infancy.

When Maxwell was young his family moved to Glenlair, in Kirkcudbrightshire, which his parents had built on the estate which comprised 1,500 acres. All indications suggest that Maxwell had maintained an unquenchable curiosity from an early age. By the age of three, everything that moved, shone, or made a noise drew the question: "what's the go o' that?" In a passage added to a letter from his father to his sister-in-law Jane Cay in 1834, his mother described this innate sense of inquisitiveness:

He is a very happy man, and has improved much since the weather got moderate; he has great work with doors, locks, keys, etc., and "show me how it doos" is never out of his mouth.

He also investigates the hidden course of streams and bell-wires, the way the water gets from the pond through the wall....

Education, 1839–1847

Recognising the boy's potential, Maxwell's mother Frances took responsibility for his early education, which in the Victorian era was largely the job of the woman of the house. At eight he could recite long passages of John Milton and the whole of the 119th psalm.

Indeed, his knowledge of scripture was already detailed; he could give chapter and verse for almost any quotation from the psalms. His mother was taken ill with abdominal cancer and, after an unsuccessful operation, died in December 1839 when he was eight years old.

His education was then overseen by his father and his father's sister-in-law Jane, both of whom played pivotal roles in his life. His formal schooling began unsuccessfully under the guidance of a 16-year-old hired tutor. Little is known about the young man hired to instruct Maxwell, except that he treated the younger boy harshly, chiding him for being slow and wayward. The tutor was dismissed in November 1841.

James' father took him to Robert Davidson's demonstration of electric propulsion and magnetic force on 12 February 1842, an experience with profound implications for the boy.

Maxwell was sent to the prestigious Edinburgh Academy. He lodged during term times at the house of his aunt Isabella. During this time his passion for drawing was encouraged by his older cousin Jemima.

The 10-year-old Maxwell, having been raised in isolation on his father's countryside estate, did not fit in well at school. The first year had been full, obliging him to join the second year with classmates a year his senior.

His mannerisms and Galloway accent struck the other boys as rustic. Having arrived on his first day of school wearing a pair of homemade shoes and a tunic, he earned the unkind nickname of "Daftie". He never seemed to resent the epithet, bearing it without complaint for many years.

Social isolation at the Academy ended when he met Lewis Campbell and Peter Guthrie Tait, two boys of a similar age who were to become notable scholars later in life. They remained lifelong friends.

Maxwell was fascinated by geometry at an early age, rediscovering the regular polyhedra before he received any formal instruction. Despite his winning the school's scripture biography prize in his second year, his academic work remained unnoticed until, at the age of 13, he won the school's mathematical medal and first prize for both English and poetry.

Maxwell's interests ranged far beyond the school syllabus and he did not pay particular attention to examination performance. He wrote his first scientific paper at the age of 14.

In it he described a mechanical means of drawing mathematical curves with a piece of twine, and the properties of ellipses, Cartesian ovals, and related curves with more than two foci.

The work, of 1846, "On the description of oval curves and those having a plurality of foci" was presented to the Royal Society of

Edinburgh by James Forbes, a professor of natural philosophy at the University of Edinburgh, because Maxwell was deemed too young to present the work himself.

The work was not entirely original, since René Descartes had also examined the properties of such multifocal ellipses in the 17th century, but Maxwell had simplified their construction.

University of Edinburgh, 1847–1850

Maxwell left the Academy in 1847 at age 16 and began attending classes at the University of Edinburgh. He had the opportunity to attend the University of Cambridge, but decided, after his first term, to complete the full course of his undergraduate studies at Edinburgh.

The academic staff of the university included some highly regarded names; his first year tutors included Sir William Hamilton, who lectured him on logic and metaphysics, Philip Kelland on mathematics, and James Forbes on natural philosophy. He did not find his classes demanding, and was therefore able to immerse himself in private study during free time at the university and particularly when back home at Glenlair.

There he would experiment with improvised chemical, electric, and magnetic apparatus; however, his chief concerns regarded the properties of polarised light. He constructed shaped blocks of gelatine, subjected them to various stresses, and with a pair of polarising prisms given to him by William Nicol, viewed the coloured fringes that had developed within the jelly.

Through this practice he discovered photoelasticity, which is a means of determining the stress distribution within physical structures.

At age 18, Maxwell contributed two papers for the Transactions of the Royal Society of Edinburgh. One of these, "On the Equilibrium of Elastic Solids", laid the foundation for an important discovery later in his life, which was the temporary double refraction produced in viscous liquids by shear stress. His other paper was "Rolling Curves" and, just as with the paper "Oval Curves" that he had written at the Edinburgh Academy, he was again considered too young to stand at the rostrum to present it himself.

The paper was delivered to the Royal Society by his tutor Kelland instead.

University of Cambridge, 1850–1856

In October 1850, already an accomplished mathematician, Maxwell left Scotland for the University of Cambridge. He initially attended Peterhouse, but before the end of his first term transferred to Trinity, where he believed it would be easier to obtain a fellowship. At Trinity he was elected to the elite secret society known as the Cambridge Apostles.

Maxwell's intellectual understanding of his Christian faith and of science grew rapidly during his Cambridge years.

He joined the "Apostles", an exclusive debating society of the intellectual elite, where through his essays he sought to work out this understanding.

Now my great plan, which was conceived of old, ... is to let nothing be wilfully left unexamined.

Nothing is to be holy ground consecrated to Stationary Faith, whether positive or negative. All fallow land is to be ploughed up and a regular system of rotation followed. ...

Never hide anything, be it weed or no, nor seem to wish it hidden. ...

Again I assert the Right of Trespass on any plot of Holy Ground which any man has set apart. ... Now I am convinced that no one but a Christian can actually purge his land of these holy spots. ...

I do not say that no Christians have enclosed places of this sort. Many have a great deal, and everyone has some. But there are extensive and important tracts in the territory of the Scoffer, the Pantheist, the Quietist, Formalist, Dogmatist, Sensualist, and the rest, which are openly and solemnly Tabooed.

Christianity—that is, the religion of the Bible—is the only scheme or form of belief which disavows any possessions on such a tenure. Here alone all is free. You may fly to the ends of the world and find no God but the Author of Salvation. You may search the Scriptures and not find a text to stop you in your explorations.

The Old Testament and the Mosaic Law and Judaism are commonly supposed to be "Tabooed" by the orthodox. Sceptics pretend to have read them and have found certain witty objections ... which too many of the orthodox unread admit, and

shut up the subject as haunted. But a Candle is coming to drive out all Ghosts and Bugbears. Let us follow the light.

In the summer of his third year, Maxwell spent some time at the Suffolk home of the Rev C.B. Tayler, the uncle of a classmate, G.W.H. Tayler. The love of God shown by the family impressed Maxwell, particularly after he was nursed back from ill health by the minister and his wife.

On his return to Cambridge, Maxwell writes to his recent host a chatty and affectionate letter including the following testimony,

I have the capacity of being more wicked than any example that man could set me, and ... if I escape, it is only by God's grace helping me to get rid of myself, partially in science, more completely in society, —but not perfectly except by committing myself to God ...

In November 1851, Maxwell studied under William Hopkins, whose success in nurturing mathematical genius had earned him the nickname of "senior wrangler-maker".

In 1854, Maxwell graduated from Trinity with a degree in mathematics. He scored second highest in the final examination, coming behind Edward Routh and earning himself the title of Second Wrangler.

He was later declared equal with Routh in the more exacting ordeal of the Smith's Prize examination.

Immediately after earning his degree, Maxwell read his paper "On the Transformation of Surfaces by Bending" to the Cambridge Philosophical Society.

This is one of the few purely mathematical papers he had written, demonstrating his growing stature as a mathematician. Maxwell decided to remain at Trinity after graduating and applied for a fellowship, which was a process that he could expect to take a couple of years.

Buoyed by his success as a research student, he would be free, apart from some tutoring and examining duties, to pursue scientific interests at his own leisure.

The nature and perception of color was one such interest which he had begun at the University of Edinburgh while he was a student of Forbes. With the coloured spinning tops invented by Forbes, Maxwell was able to demonstrate that white light would result from a mixture of red, green, and blue light.

His paper "Experiments on Color" laid out the principles of color combination and was presented to the Royal Society of Edinburgh in March 1855.

Maxwell was this time able to deliver it himself.

Maxwell was made a fellow of Trinity on 10 October 1855, sooner than was the norm, and was asked to prepare lectures on hydrostatics and optics and to set examination papers. The following February he was urged by Forbes to apply for the newly vacant Chair of Natural Philosophy at Marischal College, Aberdeen.

His father assisted him in the task of preparing the necessary references, but died on 2 April at Glenlair before either knew the result of Maxwell's candidacy.

He accepted the professorship at Aberdeen, leaving Cambridge in November 1856.

Marischal College, Aberdeen, 1856–1860

The 25-year-old Maxwell was a good 15 years younger than any other professor at Marischal. He engaged himself with his new responsibilities as head of a department, devising the syllabus and preparing lectures.

He committed himself to lecturing 15 hours a week, including a weekly pro bono lecture to the local working men's college.

He lived in Aberdeen with his cousin William Dyce Cay, a Scottish civil engineer, during the six months of the academic year and spent the summers at Glenlair, which he had inherited from his father.

He focused his attention on a problem that had eluded scientists for 200 years: the nature of Saturn's rings. It was unknown how they could remain stable without breaking up, drifting away or crashing into Saturn.

The problem took on a particular resonance at that time because St John's College, Cambridge, had chosen it as the topic for the 1857 Adams Prize.

Maxwell devoted two years to studying the problem, proving that a regular solid ring could not be stable, while a fluid ring would be forced by wave action to break up into blobs.

Since neither was observed, he concluded that the rings must be composed of numerous small particles he called "brick-bats", each independently orbiting Saturn.

Maxwell was awarded the £130 Adams Prize in 1859 for his essay "On the stability of the motion of Saturn's rings"; he was the only entrant to have made enough headway to submit an entry.

His work was so detailed and convincing that when George Biddell Airy read it he commented, "It is one of the most remarkable applications of mathematics to physics that I have ever seen." It was considered the final word on the issue until direct observations by the Voyager flybys of the 1980s confirmed Maxwell's prediction that the rings were composed of particles.

It is now understood, however, that the rings' particles are not stable at all, being pulled by gravity onto Saturn. The rings are expected to vanish entirely over the next 300 million years.

In 1857 Maxwell befriended the Reverend Daniel Dewar, who was then the Principal of Marischal. Through him Maxwell met Dewar's daughter, Katherine Mary Dewar.

They were engaged in February 1858 and married in Aberdeen on 2 June 1858. On the marriage record, Maxwell is listed as Professor of Natural Philosophy in Marischal College, Aberdeen.

Katherine was seven years Maxwell's senior. Comparatively little is known of her, although it is known that she helped in his lab and worked on experiments in viscosity.

Maxwell's biographer and friend, Lewis Campbell, adopted an uncharacteristic reticence on the subject of Katherine, though describing their married life as "one of unexampled devotion".

In 1860 Marischal College merged with the neighbouring King's College to form the University of Aberdeen. There was no room for two professors of Natural Philosophy, so Maxwell, despite his scientific reputation, found himself laid off. He was unsuccessful in applying for Forbes's recently vacated chair at Edinburgh, the post instead going to Tait.

Maxwell was granted the Chair of Natural Philosophy at King's College, London, instead. After recovering from a near-fatal bout of smallpox in 1860, he moved to London with his wife.

King's College, London, 1860–1865

Maxwell's time at King's was probably the most productive of his career. He was awarded the Royal Society's Rumford Medal in 1860 for his work on colour and was later elected to the Society in 1861.

This period of his life would see him display the world's first light-fast color photograph, further develop his ideas on the viscosity of gases, and propose a system of defining physical quantities—now known as dimensional analysis.

Maxwell would often attend lectures at the Royal Institution, where he came into regular contact with Michael Faraday.

The relationship between the two men could not be described as being close, because Faraday was 40 years Maxwell's senior and showed signs of senility. They nevertheless maintained a strong respect for each other's talents.

This time is especially noteworthy for the advances Maxwell made in the fields of electricity and magnetism.

He examined the nature of both electric and magnetic fields in his two-part paper "On physical lines of force", which was published in 1861. In it he provided a conceptual model for electromagnetic induction, consisting of tiny spinning cells of magnetic flux.

Two more parts were later added to and published in that same paper in early 1862. In the first additional part he discussed the nature of electrostatics and displacement current. In the second additional part, he dealt with the rotation of the plane of the polarisation of light in a magnetic field, a phenomenon that had been discovered by Faraday and is now known as the Faraday effect.

Later years, 1865–1879

In 1865 Maxwell resigned the chair at King's College, London, and returned to Glenlair with Katherine. In his paper "On governors" (1868) he mathematically described the behaviour of governors—devices that control the speed of steam engines—thereby establishing the theoretical basis of control engineering.

In his paper "On reciprocal figures, frames and diagrams of forces" (1870) he discussed the rigidity of various designs of lattice. He wrote the textbook Theory of Heat (1871) and the treatise Matter and Motion (1876).

Maxwell was also the first to make explicit use of dimensional analysis, in 1871.

In 1871 he returned to Cambridge to become the first Cavendish Professor of Physics.

Maxwell was put in charge of the development of the Cavendish Laboratory, supervising every step in the progress of the building and of the purchase of the collection of apparatus.

One of Maxwell's last great contributions to science was the editing (with copious original notes) of the research of Henry Cavendish, from which it appeared that Cavendish researched, amongst other things, such questions as the density of the Earth and the composition of water.

He was elected as a member to the American Philosophical Society in 1876.

In April 1879 Maxwell began to have difficulty in swallowing, the first symptom of his fatal illness.

Maxwell died in Cambridge of abdominal cancer on 5 November 1879 at the age of 48. His mother had died at the same age of the same type of cancer.

The minister who regularly visited him in his last weeks was astonished at his lucidity and the immense power and scope of his memory, but comments more particularly, ... his illness drew out the whole heart and soul and spirit of the man: his firm and undoubting faith in the Incarnation and all its results; in the full sufficiency of the Atonement; in the work of the Holy Spirit.

He had gauged and fathomed all the schemes and systems of philosophy, and had found them utterly empty and unsatisfying—"unworkable" was his own word about them—and he turned with simple faith to the Gospel of the Saviour.

As death approached Maxwell told a Cambridge colleague,

I have been thinking how very gently I have always been dealt with. I have never had a violent shove all my life.

The only desire which I can have is like David to serve my own generation by the will of God, and then fall asleep. Maxwell is buried at Parton Kirk, near Castle Douglas in Galloway close to where he grew up.

The extended biography The Life of James Clerk Maxwell, by his former schoolfellow and lifelong friend Professor Lewis Campbell, was published in 1882. His collected works were issued in two volumes by the Cambridge University Press in 1890.

The executors of Maxwell's estate were his physician George Edward Paget, G. G. Stokes, and Colin Mackenzie, who was Maxwell's cousin. Overburdened with work, Stokes passed Maxwell's papers to William Garnett, who had effective custody of the papers until about 1884.

There is a memorial inscription to him near the choir screen at Westminster Abbey.

Personal life

As a great lover of Scottish poetry, Maxwell memorised poems and wrote his own. The best known is Rigid Body Sings, closely based on "Comin' Through the Rye" by Robert Burns, which he apparently used to sing while accompanying himself on a guitar.

It has the opening lines

Gin a body meet a body

Flyin' through the air.

Gin a body hit a body,

Will it fly? And where?

A collection of his poems was published by his friend Lewis Campbell in 1882.

Descriptions of Maxwell remark upon his remarkable intellectual qualities being matched by social awkwardness. Maxwell was an evangelical Presbyterian and in his later years became an Elder of the Church of Scotland.

Maxwell's religious beliefs and related activities have been the focus of a number of papers. Attending both Church of Scotland (his father's denomination) and Episcopalian (his mother's denomination) services as a child, Maxwell underwent an evangelical conversion in April 1853. One facet of this conversion may have aligned him with an ant positivist position.

Scientific legacy: Electromagnetism

Maxwell had studied and commented on electricity and magnetism as early as 1855 when his paper "On Faraday's lines of force" was read to the Cambridge Philosophical Society. The paper presented a simplified model of Faraday's work and how electricity and magnetism are related.

He reduced all of the current knowledge into a linked set of differential equations with 20 equations in 20 variables. This work was later published as "On Physical Lines of Force" in March 1861.

Around 1862, while lecturing at King's College, Maxwell calculated that the speed of propagation of an electromagnetic field is approximately that of the speed of light.

He considered this to be more than just a coincidence, commenting, "We can scarcely avoid the conclusion that light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena.

Working on the problem further, Maxwell showed that the equations predict the existence of waves of oscillating electric and magnetic fields that travel through empty space at a speed that could be predicted from simple electrical experiments; using the data available at the time, Maxwell obtained a velocity of 310,740,000 metres per second (1.0195×109 ft/s).

In his 1865 paper "A Dynamical Theory of the Electromagnetic Field", Maxwell wrote, "The agreement of the results seems to show that light and magnetism are affections of the same substance, and that light is an electromagnetic disturbance propagated through the field according to electromagnetic laws".

Volumes I and II of "A Treatise on Electricity and Magnetism" (1873)

Volumes I and II of "A Treatise on Electricity and Magnetism" (1873)

His famous twenty equations, in their modern form of partial differential equations, first appeared in fully developed form in his textbook A Treatise on Electricity and Magnetism in 1873.

Most of this work was done by Maxwell at Glenlair during the period between holding his London post and his taking up the Cavendish chair. Oliver Heaviside reduced the complexity of Maxwell's theory down to four partial differential equations, known now collectively as Maxwell's Laws or Maxwell's equations.

Although potentials became much less popular in the nineteenth century, the use of scalar and vector potentials is now standard in the solution of Maxwell's equations.

As Barrett and Grimes (1995) describe: Maxwell expressed electromagnetism in the algebra of quaternions and made the electromagnetic potential the centerpiece of his theory. In 1881 Heaviside replaced the electromagnetic potential field by force fields as the centerpiece of electromagnetic theory.

According to Heaviside, the electromagnetic potential field was arbitrary and needed to be "assassinated". A few years later there was a debate between Heaviside and Tate about the relative merits of vector analysis and quaternions. The result was the realization that there was no need for the greater physical insights provided by quaternions if the theory was purely local, and vector analysis became commonplace.

Maxwell was proved correct, and his quantitative connection between light and electromagnetism is considered one of the great accomplishments of 19th-century mathematical physics.

Heinrich Hertz said of Maxwell's equations, "It is impossible to study this wonderful theory without feeling as if the mathematical equations had an independent life and intelligence of their own, as if they were wiser than ourselves,

indeed wiser than their discoverer, as if they gave forth more than he put into them." Hertz used Maxwell's equations to produce radio waves, leading to the invention of radar and much else.

Maxwell also introduced the concept of the electromagnetic field in comparison to force lines that Faraday described. By understanding the propagation of electromagnetism as a field emitted by active particles, Maxwell could advance his work on light. At that time, Maxwell believed that the propagation of light required a medium for the waves, dubbed the luminiferous aether.

Over time, the existence of such a medium, permeating all space and yet apparently undetectable by mechanical means, proved impossible to reconcile with experiments such as the Michelson–Morley experiment.

Moreover, it seemed to require an absolute frame of reference in which the equations were valid, with the distasteful result that the equations changed form for a moving observer.

These difficulties inspired Albert Einstein to formulate the theory of special relativity; in the process Einstein dispensed with the requirement of a stationary luminiferous aether.

Colour vision

Along with most physicists of the time, Maxwell had a strong interest in psychology.

Following in the steps of Isaac Newton and Thomas Young, he was particularly interested in the study of colour vision.

From 1855 to 1872, Maxwell published at intervals a series of investigations concerning the perception of colour, colour-blindness, and colour theory, and was awarded the Rumford Medal for "On the Theory of Colour Vision".

Isaac Newton had demonstrated, using prisms, that white light, such as sunlight, is composed of a number of monochromatic components which could then be recombined into white light.

Newton also showed that an orange paint made of yellow and red could look exactly like a monochromatic orange light, although being composed of two monochromatic yellow and red lights. Hence the paradox that puzzled physicists of the time: two complex lights (composed of more than one monochromatic light) could look alike but be physically different, called metamers.

Thomas Young later proposed that this paradox could be explained by colours being perceived through a limited number of channels in the eyes, which he proposed to be threefold, the trichromatic colour theory.

Maxwell used the recently developed linear algebra to prove Young's theory. Any monochromatic light stimulating three receptors should be able to be equally stimulated by a set of three different monochromatic lights (in fact, by any set of three different lights).

He demonstrated that to be the case, inventing colour matching experiments and Colourimetry.

Maxwell was also interested in applying his theory of colour perception, namely in colour photography. Stemming directly

from his psychological work on colour perception: if a sum of any three lights could reproduce any perceivable colour, then colour photographs could be produced with a set of three coloured filters.

In the course of his 1855 paper, Maxwell proposed that, if three black-and-white photographs of a scene were taken through red, green, and blue filters, and transparent prints of the images were projected onto a screen using three projectors equipped with similar filters, when superimposed on the screen the result would be perceived by the human eye as a complete reproduction of all the colours in the scene.

During an 1861 Royal Institution lecture on colour theory, Maxwell presented the world's first demonstration of colour photography by this principle of three-colour analysis and synthesis. Thomas Sutton, inventor of the single-lens reflex camera, took the picture.

He photographed a tartan ribbon three times, through red, green, and blue filters, also making a fourth photograph through a yellow filter, which, according to Maxwell's account, was not used in the demonstration.

Because Sutton's photographic plates were insensitive to red and barely sensitive to green, the results of this pioneering experiment were far from perfect.

It was remarked in the published account of the lecture that "if the red and green images had been as fully photographed as the blue", it "would have been a truly-coloured image of the riband.

By finding photographic materials more sensitive to the less refrangible rays, the representation of the colours of objects might be greatly improved.

Researchers in 1961 concluded that the seemingly impossible partial success of the red-filtered exposure was due to ultraviolet light, which is strongly reflected by some red dyes, not entirely blocked by the red filter used, and within the range of sensitivity of the wet collodion process Sutton employed.

Kinetic theory and thermodynamics

Maxwell also investigated the kinetic theory of gases. Originating with Daniel Bernoulli, this theory was advanced by the successive labours of John Herapath, John James Waterston, James Joule, and particularly Rudolf Clausius, to such an extent as to put its general accuracy beyond a doubt; but it received enormous development from Maxwell, who in this field appeared as an experimenter (on the laws of gaseous friction) as well as a mathematician.

Between 1859 and 1866, he developed the theory of the distributions of velocities in particles of a gas, work later generalised by Ludwig Boltzmann. The formula, called the Maxwell–Boltzmann distribution, gives the fraction of gas molecules moving at a specified velocity at any given temperature. In the kinetic theory, temperatures and heat involve only molecular movement.

This approach generalised the previously established laws of thermodynamics and explained existing observations and experiments in a better way than had been achieved previously.

His work on thermodynamics led him to devise the thought experiment that came to be known as Maxwell's demon, where the second law of thermodynamics is violated by an imaginary being capable of sorting particles by energy.

In 1871, he established Maxwell's thermodynamic relations, which are statements of equality among the second derivatives of the thermodynamic potentials with respect to different thermodynamic variables.

In 1874, he constructed a plaster thermodynamic visualisation as a way of exploring phase transitions, based on the American scientist Josiah Willard Gibbs's graphical thermodynamics papers.

About Werner Heisenberg

Werner Karl Heisenberg; 5 December 1901 – 1 February 1976) was a German theoretical physicist and one of the main pioneers of the theory of quantum mechanics.

He published his work in 1925 in a major breakthrough paper. In the subsequent series of papers with Max Born and Pascual Jordan, during the same year, his matrix formulation of quantum mechanics was substantially elaborated.

He is known for the uncertainty principle, which he published in 1927. Heisenberg was awarded the 1932 Nobel Prize in Physics "for the creation of quantum mechanics".

Heisenberg also made contributions to the theories of the hydrodynamics of turbulent flows, the atomic nucleus, ferromagnetism, cosmic rays, and subatomic particles.

He was a principal scientist in the German nuclear weapons program during World War II. He was also instrumental in planning the first West German nuclear reactor at Karlsruhe, together with a research reactor in Munich, in 1957.

Following World War II, he was appointed director of the Kaiser Wilhelm Institute for Physics, which soon thereafter was renamed the Max Planck Institute for Physics. He was director of the institute until it was moved to Munich in 1958.

He then became director of the Max Planck Institute for Physics and Astrophysics from 1960 to 1970.

Heisenberg was also president of the German Research Council, chairman of the Commission for Atomic Physics, chairman of the Nuclear Physics Working Group, and president of the Alexander von Humboldt Foundation.

Early life and education

Werner Karl Heisenberg was born in Würzburg, Germany, to Kaspar Ernst August Heisenberg, and his wife, Annie Wecklein. His father was a secondary school teacher of classical languages who became Germany's only ordentlicher Professor (ordinarius professor) of medieval and modern Greek studies in the university system.

Heisenberg was raised and lived as a Lutheran Christian. In his late teenage years, Heisenberg read Plato's Timaeus while hiking in the Bavarian Alps.

He recounted philosophical conversations with his fellow students and teachers about understanding the atom while

receiving his scientific training in Munich, Göttingen and Copenhagen.

Heisenberg later stated that "My mind was formed by studying philosophy, Plato and that sort of thing”. and that "Modern physics has definitely decided in favor of Plato.

In fact, the smallest units of matter are not physical objects in the ordinary sense; they are forms, ideas which can be expressed unambiguously only in mathematical language".

In 1919 Heisenberg arrived in Munich as a member of the Freikorps to fight the Bavarian Soviet Republic established a year earlier.

Five decades later he recalled those days as youthful fun, like "playing cops and robbers and so on; it was nothing serious at all;" his duties were restricted to "seizing bicycles or typewriters from 'red' administrative buildings", and guarding suspected "red" prisoners.

University studies

From 1920 to 1923, he studied physics and mathematics at the Ludwig Maximilian University of Munich under Arnold Sommerfeld and Wilhelm Wien and at the Georg-August University of Göttingen with Max Born and James Franck and mathematics with David Hilbert.

He received his doctorate in 1923 at Munich under Sommerfeld. At Göttingen, under Born, he completed his habilitation in 1924 with a Habilitationsschrift (habilitation thesis) on the anomalous Zeeman effect.

In June 1922, Sommerfeld took Heisenberg to Göttingen to attend the Bohr Festival, because Sommerfeld had a sincere interest in his students and knew of Heisenberg's interest in Niels Bohr's theories on atomic physics. At the event, Bohr was a guest lecturer and gave a series of comprehensive lectures on quantum atomic physics and Heisenberg met Bohr for the first time, which had a lasting effect on him.

Heisenberg's doctoral thesis, the topic of which was suggested by Sommerfeld, was on turbulence; the thesis discussed both the stability of laminar flow and the nature of turbulent flow. The problem of stability was investigated by the use of the Orr–Sommerfeld equation, a fourth order linear differential equation for small disturbances from laminar flow.

He briefly returned to this topic after World War II. In his youth he was a member and Scoutleader of the Neupfadfinder, a German Scout association and part of the German Youth Movement. In August 1923 Robert Honsell and Heisenberg organized a trip to Finland with a Scout group of this association from Munich.

Personal life

Heisenberg enjoyed classical music and was an accomplished pianist. His interest in music led to meeting his future wife. In January 1937, Heisenberg met Elisabeth Schumacher (1914–1998) at a private music recital. Elisabeth was the daughter of a well-known Berlin economics professor, and her brother was the economist E. F. Schumacher, author of Small Is Beautiful. eisenberg married her on 29 April.

Fraternal twins Maria and Wolfgang were born in January 1938, whereupon Wolfgang Pauli congratulated Heisenberg on his "pair creation"—a word play on a process from elementary particle physics, pair production.

They had five more children over the next 12 years: Barbara, Christine, Jochen, Martin and Verena. In 1936 he bought a summer home for his family in Urfeld am Walchensee, in southern Germany.

Academic career : Göttingen, Copenhagen and Leipzig

From 1924 to 1927, Heisenberg was a Privatdozent at Göttingen, meaning he was qualified to teach and examine independently, without having a chair.

From 17 September 1924 to 1 May 1925, under an International Education Board Rockefeller Foundation fellowship, Heisenberg went to do research with Niels Bohr, director of the Institute of Theoretical Physics at the University of Copenhagen. His seminal paper, "Über quantentheoretische Umdeutung kinematischer und mechanischer Beziehungen" ("Quantum theoretical re-interpretation of kinematic and mechanical relations"), was published in September 1925. He returned to Göttingen and, with Max Born and Pascual Jordan over a period of about six months, developed the matrix mechanics formulation of quantum mechanics.

On 1 May 1926, Heisenberg began his appointment as a university lecturer and assistant to Bohr in Copenhagen. It was in Copenhagen, in 1927, that Heisenberg developed his uncertainty principle, while working on the mathematical foundations of quantum mechanics.

On 23 February, Heisenberg wrote a letter to fellow physicist Wolfgang Pauli, in which he first described his new principle. In his paper on the principle, Heisenberg used the word "Ungenauigkeit" (imprecision), not uncertainty, to describe it.

In 1927, Heisenberg was appointed ordentlicher Professor (professor ordinarius) of theoretical physics and head of the department of physics at the University of Leipzig; he gave his inaugural lecture there on 1 February 1928. In his first paper published from Leipzig, Heisenberg used the Pauli exclusion principle to solve the mystery of ferromagnetism.

During Heisenberg's tenure at Leipzig, the high quality of the doctoral students and post-graduate and research associates who studied and worked with him is clear from the acclaim many later earned. At various times they included Erich Bagge, Felix Bloch, Ugo Fano, Siegfried Flügge, William Vermillion Houston, Friedrich Hund, Robert S. Mulliken, Rudolf Peierls, George Placzek, Isidor Isaac Rabi, Fritz Sauter, John C. Slater, Edward Teller, John Hasbrouck van Vleck, Victor Frederick Weisskopf, Carl Friedrich von Weizsäcker, Gregor Wentzel, and Clarence Zener.

In early 1929, Heisenberg and Pauli submitted the first of two papers laying the foundation for relativistic quantum field theory.

Also in 1929, Heisenberg went on a lecture tour of China, Japan, India, and the United States.

In the spring of 1929, he was a visiting lecturer at the University of Chicago, where he lectured on quantum mechanics.

In 1928, the British mathematical physicist Paul Dirac had derived his relativistic wave equation of quantum mechanics, which implied the existence of positive electrons, later to be named positrons. In 1932, from a cloud chamber photograph of cosmic rays, the American physicist Carl David Anderson identified a track as having been made by a positron.

In mid-1933, Heisenberg presented his theory of the positron. His thinking on Dirac's theory and further development of the theory were set forth in two papers. The first, "Bemerkungen zur Diracschen Theorie des Positrons" ("Remarks on Dirac's theory of the positron") was published in 1934, and the second, "Folgerungen aus der Diracschen Theorie des Positrons" ("Consequences of Dirac's Theory of the Positron"), was published in 1936.

In these papers Heisenberg was the first to reinterpret the Dirac equation as a "classical" field equation for any point particle of spin ħ/2, itself subject to quantization conditions involving anti-commutators. Thus reinterpreting it as a (quantum) field equation accurately describing electrons, Heisenberg put matter on the same footing as electromagnetism: as being described by relativistic quantum field equations which allowed the possibility of particle creation and destruction.

(Hermann Weyl had already described this in a 1929 letter to Albert Einstein).

Matrix mechanics and the Nobel Prize

Heisenberg's paper establishing quantum mechanics has puzzled physicists and historians.

His methods assume that the reader is familiar with Kramers-Heisenberg transition probability calculations. The main new idea, non-commuting matrices, is justified only by a rejection of unobservable quantities.

It introduces the non-commutative multiplication of matrices by physical reasoning, based on the correspondence principle, despite the fact that Heisenberg was not then familiar with the mathematical theory of matrices. The path leading to these results has been reconstructed in MacKinnon, 1977, and the detailed calculations are worked out in Aitchison et al.

In Copenhagen, Heisenberg and Hans Kramers collaborated on a paper on dispersion, or the scattering from atoms of radiation whose wavelength is larger than the atoms. They showed that the successful formula Kramers had developed earlier could not be based on Bohr orbits, because the transition frequencies are based on level spacings which are not constant.

The frequencies which occur in the Fourier transform of sharp classical orbits, by contrast, are equally spaced. But these results could be explained by a semi-classical virtual state model: the incoming radiation excites the valence, or outer, electron to a virtual state from which it decays.

In a subsequent paper Heisenberg showed that this virtual oscillator model could also explain the polarization of fluorescent radiation.

These two successes, and the continuing failure of the Bohr–Sommerfeld model to explain the outstanding problem of the anomalous Zeeman effect, led Heisenberg to use the virtual oscillator model to try to calculate spectral frequencies.

The method proved too difficult to immediately apply to realistic problems, so Heisenberg turned to a simpler example, the anharmonic oscillator.

The dipole oscillator consists of a simple harmonic oscillator, which is thought of as a charged particle on a spring, perturbed by an external force, like an external charge. The motion of the oscillating charge can be expressed as a Fourier series in the frequency of the oscillator.

Heisenberg solved for the quantum behavior by two different methods.

First, he treated the system with the virtual oscillator method, calculating the transitions between the levels that would be produced by the external source.

He then solved the same problem by treating the anharmonic potential term as a perturbation to the harmonic oscillator and using the perturbation methods that he and Born had developed.

Both methods led to the same results for the first and the very complicated second order correction terms.

This suggested that behind the very complicated calculations lay a consistent scheme.

So Heisenberg set out to formulate these results without any explicit dependence on the virtual oscillator model.

To do this, he replaced the Fourier expansions for the spatial coordinates by matrices, matrices which corresponded to the transition coefficients in the virtual oscillator method.

He justified this replacement by an appeal to Bohr's correspondence principle and the Pauli doctrine that quantum mechanics must be limited to observables.

On 9 July, Heisenberg gave Born this paper to review and submit for publication. When Born read the paper, he recognized the formulation as one which could be transcribed and extended to the systematic language of matrices, which he had learned from his study under Jakob Rosanes at Breslau University.

Born, with the help of his assistant and former student Pascual Jordan, began immediately to make the transcription and extension, and they submitted their results for publication; the paper was received for publication just 60 days after Heisenberg's paper. A follow-on paper was submitted for publication before the end of the year by all three authors.

Up until this time, matrices were seldom used by physicists; they were considered to belong to the realm of pure mathematics. Gustav Mie had used them in a paper on electrodynamics in 1912 and Born had used them in his work on the lattice theory of crystals in 1921.

While matrices were used in these cases, the algebra of matrices with their multiplication did not enter the picture as they did in the matrix formulation of quantum mechanics.

In 1928, Albert Einstein nominated Heisenberg, Born, and Jordan for the Nobel Prize in Physics, the announcement of the Nobel Prize in Physics for 1932 was delayed until November 1933.

It was at that time that it was announced Heisenberg had won the Prize for 1932 "for the creation of quantum mechanics, the application of which has, inter alia, led to the discovery of the allotropic forms of hydrogen".

Interpretation of quantum theory

The development of quantum mechanics, and the apparent contradictory implications in regard to what is "real" had profound philosophical implications, including what scientific observations truly mean.

In contrast to Albert Einstein and Louis de Broglie, who were realists who believed that particles had an objectively true momentum and position at all times (even if both could not be measured), Heisenberg was an anti-realist, arguing that direct knowledge of what is "real" was beyond the scope of science.

Writing in his book The Physicist's Conception of Nature, Heisenberg argued that ultimately we only can speak of the knowledge (numbers in tables) which describe something about particles but we can never have any "true" access to the particles themselves: We can no longer speak of the behaviour of the particle independently of the process of observation. As a final consequence, the natural laws formulated mathematically in quantum theory no longer deal with the elementary particles themselves but with our knowledge of them.

Nor is it any longer possible to ask whether or not these particles exist in space and time objectively ... When we speak of the picture of nature in the exact science of our age, we do not mean a picture of nature so much as a picture of our relationships with nature. ...

Science no longer confronts nature as an objective observer, but sees itself as an actor in this interplay between man and nature. The scientific method of analysing, explaining and classifying has become conscious of its limitations, which arise out of the fact that by its intervention science alters and refashions the object of investigation. In other words, method and object can no longer be separated.

SS investigation

Shortly after the discovery of the neutron by James Chadwick in 1932, Heisenberg submitted the first of three papers on his neutron-proton model of the nucleus. After Adolf Hitler came to power in 1933, Heisenberg was attacked in the press as a "White Jew" (i.e. an Aryan who acts like a Jew).

Supporters of Deutsche Physik, or German Physics (also known as Aryan Physics), launched vicious attacks against leading theoretical physicists, including Arnold Sommerfeld and Heisenberg.

From the early 1930s onward, the anti-Semitic and anti-theoretical physics movement Deutsche Physik had concerned itself with quantum mechanics and the theory of relativity. As applied in the university environment, political factors took priority over scholarly ability, even though its two most prominent supporters were the Nobel Laureates in Physics Philipp Lenard and Johannes Stark.

There had been many failed attempts to have Heisenberg appointed as professor at a number of German universities. His attempt to be appointed as successor to Arnold Sommerfeld failed because of opposition by the Deutsche Physik movement.

On 1 April 1935, the eminent theoretical physicist Sommerfeld, Heisenberg's doctoral advisor at the Ludwig-Maximilians-Universität München, achieved emeritus status. However, Sommerfeld stayed in his chair during the selection process for his successor, which took until 1 December 1939.

The process was lengthy due to academic and political differences between the Munich Faculty's selection and that of the Reich Education Ministry and the supporters of Deutsche Physik.

In 1935, the Munich Faculty drew up a list of candidates to replace Sommerfeld as ordinarius professor of theoretical physics and head of the Institute for Theoretical Physics at the University of Munich.

The three candidates had all been former students of Sommerfeld: Heisenberg, who had received the Nobel Prize in Physics; Peter Debye, who had received the Nobel Prize in Chemistry in 1936; and Richard Becker. The Munich Faculty was firmly behind these candidates, with Heisenberg as their first choice.

However, supporters of Deutsche Physik and elements in the REM had their own list of candidates, and the battle dragged on for over four years. During this time, Heisenberg came under vicious attack by the Deutsche Physik supporters.

One attack was published in Das Schwarze Korps, the newspaper of the SS, headed by Heinrich Himmler. In this, Heisenberg was called a "White Jew" who should be made to "disappear". These attacks were taken seriously, as Jews were violently attacked and incarcerated.

Heisenberg fought back with an editorial and a letter to Himmler, in an attempt to resolve the matter and regain his honour.

At one point, Heisenberg's mother visited Himmler's mother. The two women knew each other, as Heisenberg's maternal grandfather and Himmler's father were rectors and members of a Bavarian hiking club. Eventually, Himmler settled the Heisenberg affair by sending two letters, one to SS Gruppenführer Reinhard Heydrich and one to Heisenberg, both on 21 July 1938.

In the letter to Heydrich, Himmler said Germany could not afford to lose or silence Heisenberg, as he would be useful for teaching a generation of scientists. To Heisenberg, Himmler said the letter came on recommendation of his family and he cautioned Heisenberg to make a distinction between professional physics research results and the personal and political attitudes of the involved scientists.

Wilhelm Müller replaced Sommerfeld at the Ludwig Maximilian University of Munich. Müller was not a theoretical physicist, had not published in a physics journal, and was not a member of the German Physical Society. His appointment was considered a travesty and detrimental to educating theoretical physicists.

The three investigators who led the SS investigation of Heisenberg had training in physics. Indeed, Heisenberg had participated in the doctoral examination of one of them at the Universität Leipzig. The most influential of the three was Johannes Juilfs.

During their investigation, they became supporters of Heisenberg as well as his position against the ideological policies of the Deutsche Physik movement in theoretical physics and academia.

German nuclear weapons program: Pre-war work on physics

In mid-1936, Heisenberg presented his theory of cosmic-ray showers in two papers. Four more papers appeared in the next two years.

In December 1938, the German chemists Otto Hahn and Fritz Strassmann sent a manuscript to The Natural Sciences reporting they had detected the element barium after bombarding uranium with neutrons and Otto Hahn concluded a bursting of the uranium nucleus; simultaneously, Hahn communicated these results to his friend Lise Meitner, who had in July of that year fled to the Netherlands and then went to Sweden. Meitner, and her nephew Otto Robert Frisch, correctly interpreted Hahn's and Strassmann's results as being nuclear fission.

Frisch confirmed this experimentally on 13 January 1939.

In June 1939, Heisenberg traveled to the United States in June and July, visiting Samuel Abraham Goudsmit at the University of Michigan in Ann Arbor. However, Heisenberg refused an invitation to emigrate to the United States.

He did not see Goudsmit again until six years later, when Goudsmit was the chief scientific advisor to the American Operation Alsos at the close of World War II.

Membership in the Uranverein

The German nuclear weapons program, known as Uranverein, was formed on 1 September 1939, the day World War II began. The Heereswaffenamt (HWA, Army Ordnance Office) had squeezed the Reichsforschungsrat (RFR, Reich Research Council) out of the Reichserziehungsministerium (REM, Reich Ministry of Education) and started the formal German nuclear energy project under military auspices.

The project had its first meeting on 16 September 1939. The meeting was organized by Kurt Diebner, advisor to the HWA, and held in Berlin. The invitees included Walther Bothe, Siegfried Flügge, Hans Geiger, Otto Hahn, Paul Harteck, Gerhard Hoffmann, Josef Mattauch and Georg Stetter. A second meeting was held soon thereafter and included Heisenberg, Klaus Clusius, Robert Döpel and Carl Friedrich von Weizsäcker.

The Kaiser-Wilhelm Institut für Physik (KWIP, Kaiser Wilhelm Institute for Physics) in Berlin-Dahlem, was placed under HWA authority, with Diebner as the administrative director, and the military control of the nuclear research commenced.

During the period when Diebner administered the KWIP under the HWA program, considerable personal and professional animosity developed between Diebner and Heisenberg's inner circle, which included Karl Wirtz and Carl Friedrich von Weizsäcker.

At a scientific conference on 26–28 February 1942 at the Kaiser Wilhelm Institute for Physics, called by the Army Weapons Office, Heisenberg presented a lecture to Reichs officials on energy acquisition from nuclear fission.

The lecture, entitled "Die theoretischen Grundlagen für die Energiegewinnung aus der Uranspaltung" ("The theoretical basis for energy generation from uranium fission") was, as Heisenberg confessed after the Second World War in a letter to Samuel Goudsmit, "adapted to the intellectual level of a Reichs Minister".

Heisenberg lectured on the enormous energy potential of nuclear fission, stating that 250 million electron volts could be released through the fission of an atomic nucleus. Heisenberg stressed that pure U-235 had to be obtained to achieve a chain reaction.

He explored various ways of obtaining isotope 235-92U.

in its pure form, including uranium enrichment and an alternative layered method of normal uranium and a moderator in a machine.

This machine, he noted, could be used in practical ways to fuel vehicles, ships and submarines. Heisenberg stressed the importance of the Army Weapons Office's financial and material support for this scientific endeavour. A second scientific conference followed.

Lectures were heard on problems of modern physics with decisive importance for the national defense and economy. The conference was attended by Bernhard Rust, the Reichs Minister of Science, Education and National Culture. At the conference Reichs Minister Rust decided to take the nuclear project away from the Kaiser Wilhelm Society. T

he Reichs Research Council was to take on the project.

In April 1942 the army returned the Physics Institute to the Kaiser Wilhelm Society, naming Heisenberg as Director at the Institute. With this appointment at the KWIP, Heisenberg obtained his first professorship. Peter Debye was still director of the institute, but had gone on leave to the United States after he had refused to become a German citizen when the HWA took administrative control of the KWIP.

Heisenberg still also had his department of physics at the University of Leipzig where work had been done for the Uranverein by Robert Döpel and his wife Klara Döpel.

On 4 June 1942, Heisenberg was summoned to report to Albert Speer, Germany's Minister of Armaments, on the prospects for converting the Uranverein's research toward developing nuclear weapons.

During the meeting, Heisenberg told Speer that a bomb could not be built before 1945, because it would require significant monetary resources and number of personnel.

After the Uranverein project was placed under the leadership of the Reichs Research Council, it focused on nuclear power production and thus maintained its kriegswichtig (importance for the war) status; funding therefore continued from the military.

The nuclear power project was broken down into the following main areas: uranium and heavy water production, uranium isotope separation and the Uranmaschine (uranium machine, i.e., nuclear reactor). The project was then essentially split up between a number of institutes, where the directors dominated the research and set their own research agendas.

The point in 1942, when the army relinquished its control of the German nuclear weapons program, was the zenith of the project relative to the number of personnel.

About 70 scientists worked for the program, with about 40 devoting more than half their time to nuclear fission research.

After 1942, the number of scientists working on applied nuclear fission diminished dramatically. Many of the scientists not working with the main institutes stopped working on nuclear fission and devoted their efforts to more pressing war-related work.

In September 1942, Heisenberg submitted his first paper of a three-part series on the scattering matrix, or S-matrix, in elementary particle physics. The first two papers were published in 1943 and the third in 1944.

The S-matrix described only the states of incident particles in a collision process, the states of those emerging from the collision, and stable bound states; there would be no reference to the intervening states.

This was the same precedent as he followed in 1925 in what turned out to be the foundation of the matrix formulation of quantum mechanics through only the use of observables.

In February 1943, Heisenberg was appointed to the Chair for Theoretical Physics at the Friedrich-Wilhelms-Universität (today, the Humboldt-Universität zu Berlin).

In April, his election to the Preußische Akademie der Wissenschaften (Prussian Academy of Sciences) was approved.

That same month, he moved his family to their retreat in Urfeld as Allied bombing increased in Berlin.

In the summer, he dispatched the first of his staff at the Kaiser-Wilhelm Institut für Physik to Hechingen and its neighboring town of Haigerloch, on the edge of the Black Forest, for the same reasons.

From 18–26 October, he travelled to German-occupied Netherlands.

In December 1943, Heisenberg visited German-occupied Poland.

From 24 January to 4 February 1944, Heisenberg travelled to occupied Copenhagen, after the German army confiscated Bohr's Institute of Theoretical Physics. He made a short return trip in April.

In December, Heisenberg lectured in neutral Switzerland.

The United States Office of Strategic Services sent agent Moe Berg to attend the lecture carrying a pistol, with orders to shoot Heisenberg if his lecture indicated that Germany was close to completing an atomic bomb. In January 1945, Heisenberg, with most of the rest of his staff, moved from the Kaiser-Wilhelm Institut für Physik to the facilities in the Black Forest.

Post-Second World War - 1945: Alsos Mission

The Alsos Mission was an Allied effort to determine if the Germans had an atomic bomb program and to exploit German atomic related facilities, research, material resources, and scientific personnel for the benefit of the US. Personnel on this operation generally swept into areas which had just come

under control of the Allied military forces, but sometimes they operated in areas still under control by German forces.

Berlin had been a location of many German scientific research facilities. To limit casualties and loss of equipment, many of these facilities were dispersed to other locations in the latter years of the war.

The Kaiser-Wilhelm-Institut für Physik (KWIP, Kaiser Wilhelm Institute for Physics) had been bombed so it had mostly been moved in 1943 and 1944 to Hechingen and its neighboring town of Haigerloch, on the edge of the Black Forest, which eventually became included in the French occupation zone.

This allowed the American task force of the Alsos Mission to take into custody a large number of German scientists associated with nuclear research.

On 30 March, the Alsos Mission reached Heidelberg, where important scientists were captured including Walther Bothe, Richard Kuhn, Philipp Lenard, and Wolfgang Gertner.

Their interrogation revealed that Otto Hahn was at his laboratory in Tailfingen, while Heisenberg and Max von Laue were at Heisenberg's laboratory in Hechingen, and that the experimental natural uranium reactor that Heisenberg's team had built in Berlin had been moved to Haigerloch.

Thereafter, the main focus of the Alsos Mission was on these nuclear facilities in the Württemberg area. Heisenberg was smuggled out from Urfeld, on 3 May 1945, in an alpine operation in territory still under control by elite German forces.

He was taken to Heidelberg, where, on 5 May, he met Goudsmit for the first time since the Ann Arbor visit in 1939. Germany surrendered just two days later.

Heisenberg would not see his family again for eight months, as he was moved across France and Belgium and flown to England on 3 July 1945.

1945: Reaction to Hiroshima

Nine of the prominent German scientists who published reports in Nuclear Physics Research Reports as members of the Uranverein were captured by Operation Alsos and incarcerated in England under Operation Epsilon. Ten German scientists, including Heisenberg, were held at Farm Hall in England. The facility had been a safe house of the British foreign intelligence MI6.

During their detention, their conversations were recorded. Conversations thought to be of intelligence value were transcribed and translated into English. The transcripts were released in 1992.

On 6 August 1945, the scientists at Farm Hall learned from media reports that the USA had dropped an atomic bomb in Hiroshima, Japan. At first, there was disbelief that a bomb had been built and dropped. In the weeks that followed, the German scientists discussed how the USA might have built the bomb.

The Farm Hall transcripts reveal that Heisenberg, along with other physicists interned at Farm Hall including Otto Hahn and Carl Friedrich von Weizsäcker, were glad the Allies had won World War II.

Heisenberg told other scientists that he had never contemplated a bomb, only an atomic pile to produce energy. The morality of creating a bomb for the Nazis was also discussed. Only a few of the scientists expressed genuine horror at the prospect of nuclear weapons, and Heisenberg himself was cautious in discussing the matter.

On the failure of the German nuclear weapons program to build an atomic bomb, Heisenberg remarked, "We wouldn't have had the moral courage to recommend to the government in the spring of 1942 that they should employ 120,000 men just for building the thing up".

Post-war research career

Executive positions at German research institutions

On 3 January 1946, the ten Operation Epsilon detainees were transported to Alswede in Germany. Heisenberg settled in Göttingen, which was in the British zone of Allied-occupied Germany. Heisenberg immediately began to promote scientific research in Germany.

Following the Kaiser Wilhelm Society's obliteration by the Allied Control Council and the establishment of the Max Planck Society in the British zone, Heisenberg became the director of the Max Planck Institute for Physics. Max von Laue was appointed vice director, while Karl Wirtz, Carl Friedrich von Weizsäcker and Ludwig Biermann joined to help Heisenberg establish the institute.

Heinz Billing joined in 1950 to promote the development of electronic computing.

The core research focus of the institute was cosmic radiation. The institute held a colloquium every Saturday morning.

Heisenberg together with Hermann Rein, was instrumental in the establishment of the Forschungsrat (research council). Heisenberg envisaged for this council to promote the dialogue between the newly founded Federal Republic of Germany and the scientific community based in Germany.

Heisenberg was appointed president of the Forschungsrat.

In 1951, the organization was fused with the Notgemeinschaft der Deutschen Wissenschaft (Emergency Association of German Science) and that same year renamed the Deutsche Forschungsgemeinschaft (German Research Foundation). Following the merger, Heisenberg was appointed to the presidium.

In 1958, the Max-Planck-Institut für Physik was moved to Munich, expanded, and renamed Max-Planck-Institut für Physik und Astrophysik (MPIFA).

In the interim, Heisenberg and the astrophysicist Ludwig Biermann were co-directors of MPIFA. Heisenberg also became an ordentlicher Professor (ordinarius professor) at the Ludwig-Maximilians-Universität München.

Heisenberg was the sole director of MPIFA from 1960 to 1970. Heisenberg resigned his directorship of the MPIFA on 31 December 1970.

Promotion of international scientific cooperation

In 1951, Heisenberg agreed to become the scientific representative of the Federal Republic of Germany at the

UNESCO conference, with the aim of establishing a European laboratory for nuclear physics. Heisenberg's aim was to build a large particle accelerator, drawing on the resources and technical skills of scientists across the Western Bloc.

On 1 July 1953 Heisenberg signed the convention that established CERN on behalf of the Federal Republic of Germany. Although he was asked to become CERN's founding scientific director, he declined. Instead, he was appointed chair of CERN's science policy committee and went on to determine the scientific program at CERN.

In December 1953, Heisenberg became the president of the Alexander von Humboldt Foundation.

During his tenure as president 550 Humboldt scholars from 78 nations received scientific research grants. Heisenberg resigned as president shortly before his death.

Research interests

In 1946, the German scientist Heinz Pose, head of Laboratory V in Obninsk, wrote a letter to Heisenberg inviting him to work in the USSR.

The letter lauded the working conditions in the USSR and the available resources, as well as the favorable attitude of the Soviets towards German scientists. A courier hand delivered the recruitment letter, dated 18 July 1946, to Heisenberg; Heisenberg politely declined.

In 1947, Heisenberg presented lectures in Cambridge, Edinburgh and Bristol.

Heisenberg contributed to the understanding of the phenomenon of superconductivity with a paper in 1947 and two papers in 1948, one of them with Max von Laue.

In the period shortly after World War II, Heisenberg briefly returned to the subject of his doctoral thesis, turbulence.

Three papers were published in 1948 and one in 1950.

In the post-war period Heisenberg continued his interests in cosmic-ray showers with considerations on multiple production of mesons.

He published three papers in 1949, two in 1952, and one in 1955.

In late 1955 to early 1956, Heisenberg gave the Gifford Lectures at St Andrews University, in Scotland, on the intellectual history of physics. The lectures were later published as Physics and Philosophy: The Revolution in Modern Science.

During 1956 and 1957, Heisenberg was the chairman of the Arbeitskreis Kernphysik (Nuclear Physics Working Group) of the Fachkommission II "Forschung und Nachwuchs" (Commission II "Research and Growth") of the Deutsche Atomkommission (DAtK, German Atomic Energy Commission).

Other members of the Nuclear Physics Working Group in both 1956 and 1957 were: Walther Bothe, Hans Kopfermann (vice-chairman), Fritz Bopp, Wolfgang Gentner, Otto Haxel, Willibald Jentschke, Heinz Maier-Leibnitz, Josef Mattauch, Wolfgang Riezler, Wilhelm Walcher and Carl Friedrich von Weizsäcker. Wolfgang Paul was also a member of the group during 1957.

In 1957, Heisenberg was a signatory of the Göttinger Manifest, taking a public stand against the Federal Republic of Germany arming itself with nuclear weapons.

Heisenberg, like Pascual Jordan, thought politicians would ignore this statement by nuclear scientists. But Heisenberg believed that the Göttinger Manifest would "influence public opinion" which politicians would have to take into account.

He wrote to Walther Gerlach: We will probably have to keep coming back to this question in public for a long time because of the danger that public opinion will slacken.

In 1961 Heisenberg signed the Memorandum of Tübingen alongside a group of scientists who had been brought together by Carl Friedrich von Weizsäcker and Ludwig Raiser. A public discussion between scientists and politicians ensued. As prominent politicians, authors and socialites joined the debate on nuclear weapons, the signatories of the memorandum took a stand against "the full-time intellectual nonconformists".

From 1957 onwards, Heisenberg was interested in plasma physics and the process of nuclear fusion. He also collaborated with the International Institute of Atomic Physics in Geneva.

He was a member of the Institute's scientific policy committee, and for several years was the Committee's chair.

He was one of the eight signatories of the Memorandum of Tübingen which called for the recognition of the Oder–Neiße line as the official border between Germany and Poland and spoke against a possible nuclear armament of West Germany.

In 1973, Heisenberg gave a lecture at Harvard University on the historical development of the concepts of quantum theory.

On 24 March 1973 Heisenberg gave a speech before the Catholic Academy of Bavaria, accepting the Romano Guardini Prize.

An English translation of his speech was published under the title "Scientific and Religious Truth", a quotation from which appears in a later section of this article.

Philosophy and worldview

Heisenberg admired Eastern philosophy and saw parallels between it and quantum mechanics, describing himself as in "complete agreement" with the book The Tao of Physics.

Heisenberg even went as far to state that after conversations with Rabindranath Tagore about Indian philosophy "some of the ideas that seemed so crazy suddenly made much more sense".

Regarding the philosophy of Ludwig Wittgenstein, Heisenberg disliked Tractatus Logico-Philosophicus but he liked "very much the later ideas of Wittgenstein and his philosophy about language".

Heisenberg, a devout Christian, wrote: "We can console ourselves that the good Lord God would know the position of the particles, thus He would let the causality principle continue to have validity", in his last letter to Albert Einstein.

Einstein continued to maintain that quantum physics must be incomplete because it implies that the universe is indeterminate at a fundamental level.

Heisenberg said "the first gulp from the glass of natural sciences will turn you into an atheist, but at the bottom of the glass God is waiting for you.

In lectures given in the 1950s and later published as Physics and Philosophy, Heisenberg contended that scientific advances were leading to cultural conflicts. He stated that modern physics is "part of a general historical process that tends toward a unification and a widening of our present world".

When Heisenberg accepted the Romano Guardini Prize, in 1974, he gave a speech, which he later published under the title Scientific and Religious Truth. He mused: In the history of science, ever since the famous trial of Galileo, it has repeatedly been claimed that scientific truth cannot be reconciled with the religious interpretation of the world.

Although I am now convinced that scientific truth is unassailable in its own field, I have never found it possible to dismiss the content of religious thinking as simply part of an outmoded phase in the consciousness of mankind, a part we shall have to give up from now on.

Thus in the course of my life I have repeatedly been compelled to ponder on the relationship of these two regions of thought, for I have never been able to doubt the reality of that to which they point.

Autobiography and death

Heisenberg's son, Martin Heisenberg, became a neurobiologist at the University of Würzburg, while his son Jochen Heisenberg

became a physics professor at the University of New Hampshire.

In his late sixties, Heisenberg penned his autobiography for the mass market.

In 1969 the book was published in Germany, in early 1971 it was published in English and in the years thereafter in a string of other languages. Heisenberg had initiated the project in 1966, when his public lectures increasingly turned to the subjects of philosophy and religion.

Heisenberg had sent the manuscript for a textbook on the unified field theory to the Hirzel Verlag and John Wiley & Sons for publication. This manuscript, he wrote to one of his publishers, was the preparatory work for his autobiography.

He structured his autobiography in themes, covering: 1)

The goal of exact science, 2)

The problematic of language in atomic physics, 3)

Abstraction in mathematics and science, 4)

The divisibility of matter or Kant's antinomy, 5)

The basic symmetry and its substantiation, and 6)

Science and religion.

Heisenberg wrote his memoirs as a chain of conversations, covering the course of his life. The book became a popular success, but was regarded as troublesome by historians of science. In the preface Heisenberg wrote that he had abridged historical events, to make them more concise.

At the time of publication it was reviewed by Paul Forman in the journal Science with the comment "Now here is a memoir in the form of rationally reconstructed dialogue. And the dialogue as Galileo well knew, is itself a most insidious literary device: lively, entertaining, and especially suited for insinuating opinions while yet evading responsibility for them".

Few scientific memoirs had been published, but Konrad Lorenz and Adolf Portmann had penned popular books that conveyed scholarship to a wide audience. Heisenberg worked on his autobiography and published it with the Piper Verlag in Munich.

Heisenberg initially proposed the title Gespräche im Umkreis der Atomphysik (Conversations on atomic physics). The autobiography was published eventually under the title Der Teil und das Ganze (The part and the whole).

The 1971 English translation was published under the title Physics and Beyond: Encounters and Conversations.

Heisenberg died of kidney cancer at his home, on 1 February 1976. The next evening, his colleagues and friends walked in remembrance from the Institute of Physics to his home, lit a candle and placed it in front of his door.

Heisenberg is buried in Munich Waldfriedhof.

In 1980 his widow, Elisabeth Heisenberg, published The Political Life of an Apolitical Person (de, Das politische Leben eines Unpolitischen). In it she characterized Heisenberg as "first and foremost, a spontaneous person, thereafter a brilliant scientist, next a highly talented artist, and only in the fourth place, from a sense of duty, homo politicus".

About Erwin Schrödinger

Erwin Rudolf Josef Alexander Schrödinger 12 August 1887 – 4 January 1961), sometimes written as Schroedinger or Schrodinger, was a Nobel Prize-winning Austrian and naturalized Irish physicist who developed fundamental results in quantum theory: The Schrödinger equation provides a way to calculate the wave function of a system and how it changes dynamically in time.

In addition, he wrote many works on various aspects of physics: statistical mechanics and thermodynamics, physics of dielectrics, colour theory, electrodynamics, general relativity, and cosmology, and he made several attempts to construct a unified field theory.

In his book What Is Life?

Schrödinger addressed the problems of genetics, looking at the phenomenon of life from the point of view of physics.

He also paid great attention to the philosophical aspects of science, ancient, and oriental philosophical concepts, ethics, and religion.

He also wrote on philosophy and theoretical biology. In popular culture, he is most known for his "Schrödinger's cat" thought experiment.

Spending most of his life as an academic with positions at various universities, Schrödinger, along with Paul Dirac, won the Nobel Prize in Physics in 1933 for his work on quantum mechanics, the same year he left Germany due to his opposition to Nazism.

In his personal life, he lived with both his wife and his mistress which may have led to problems causing him to leave his position at Oxford.

Subsequently, until 1938, he had a position in Graz, Austria, until the Nazi takeover when he fled, finally finding a long-term arrangement in Dublin where he remained until retirement in 1955. He died in Vienna of tuberculosis when he was 73.

Biography: Early years

Schrödinger was born in Erdberg , Vienna, Austria, on 12 August 1887, to Rudolf Schrödinger (cerecloth producer, botanist) and Georgine Emilia Brenda Schrödinger (née Bauer) (daughter of Alexander Bauer , professor of chemistry, TU Wien).

He was their only child.

His mother was of half Austrian and half English descent; his father was Catholic and his mother was Lutheran. Although he was raised in a religious household as a Lutheran, he himself was an atheist.

However, he had strong interests in Eastern religions and pantheism, and he used religious symbolism in his works. He also believed his scientific work was an approach to Divinity, albeit in an intellectual sense.

He was also able to learn English outside school, as his maternal grandmother was British.

Between 1906 and 1910 (the year he earned his doctorate) Schrödinger studied at the University of Vienna under the physicists Franz S. Exner (1849–1926) and Friedrich Hasenöhrl (1874–1915).

He received his doctorate at Vienna under Hasenöhrl. He also conducted experimental work with Karl Wilhelm Friedrich "Fritz" Kohlrausch. In 1911, Schrödinger became an assistant to Exner.

Middle years

In 1914 Schrödinger achieved habilitation (venia legendi). Between 1914 and 1918 he participated in war work as a commissioned officer in the Austrian fortress artillery (Gorizia, Duino, Sistiana, Prosecco, Vienna). In 1920 he became the assistant to Max Wien, in Jena, and in September 1920 he attained the position of ao.

Prof. (ausserordentlicher Professor), roughly equivalent to Reader (UK) or associate professor (US), in Stuttgart. In 1921, he became o.

Prof. (ordentlicher Professor, i.e. full professor), in Breslau (now Wrocław, Poland). In 1921, he moved to the University of Zürich.

In 1927, he succeeded Max Planck at the Friedrich Wilhelm University in Berlin.

In 1933, Schrödinger decided to leave Germany because he strongly disapproved of the Nazis' antisemitism. He became a Fellow of Magdalen College at the University of Oxford. Soon after he arrived, he received the Nobel Prize together with Paul Dirac.

His position at Oxford did not work out well; his unconventional domestic arrangements, sharing living quarters with two women, were not met with acceptance.

In 1934, Schrödinger lectured at Princeton University; he was offered a permanent position there, but did not accept it. Again, his wish to set up house with his wife and his mistress may have created a problem.

He had the prospect of a position at the University of Edinburgh but visa delays occurred, and in the end he took up a position at the University of Graz in Austria in 1936. He had also accepted the offer of chair position at Department of Physics, Allahabad University in India.

In the midst of these tenure issues in 1935, after extensive correspondence with Albert Einstein, he proposed what is now called the Schrödinger's cat thought experiment.

Later years

In 1938, after the Anschluss, Schrödinger had problems in Graz because of his flight from Germany in 1933 and his known opposition to Nazism.

He issued a statement recanting this opposition (he later regretted doing so and explained the reason to Einstein).

However, this did not fully appease the new dispensation and the University of Graz dismissed him from his post for political unreliability. He suffered harassment and was instructed not to leave the country. He and his wife, however, fled to Italy.

From there, he went to visiting positions in Oxford and Ghent University.

In the same year he received a personal invitation from Ireland's Taoiseach, Éamon de Valera – a mathematician

himself – to reside in Ireland and agreed to help establish an Institute for Advanced Studies in Dublin.

He moved to Kincora Road, Clontarf, Dublin, and lived modestly. A plaque has been erected at his Clontarf residence and at the address of his workplace in Merrion Square. Schrodinger believed that as an Austrian he had a unique relationship to Ireland.

In October 1940, a writer from the Irish Press interviewed Schrodinger who spoke of Celtic heritage of Austrians, saying: "I believe there is a deeper connection between us Austrians and the Celts.

Names of places in the Austrian Alps are said to be of Celtic origin." He became the Director of the School for Theoretical Physics in 1940 and remained there for 17 years.

He became a naturalized Irish citizen in 1948, but also retained his Austrian citizenship.

He wrote around 50 further publications on various topics, including his explorations of unified field theory.

In 1944, he wrote What Is Life?

which contains a discussion of negentropy and the concept of a complex molecule with the genetic code for living organisms. According to James D. Watson's memoir, DNA, the Secret of Life, Schrödinger's book gave Watson the inspiration to research the gene, which led to the discovery of the DNA double helix structure in 1953.

Similarly, Francis Crick, in his autobiographical book What Mad Pursuit, described how he was influenced by Schrödinger's

speculations about how genetic information might be stored in molecules.

Schrödinger stayed in Dublin until retiring in 1955.

A manuscript "Fragment from an unpublished dialogue of Galileo" from this time recently resurfaced at The King's Hospital boarding school, Dublin after it was written for the School's 1955 edition of their Blue Coat to celebrate his leaving of Dublin to take up his appointment as Chair of Physics at the University of Vienna.

In 1956, he returned to Vienna (chair ad personam). At an important lecture during the World Energy Conference he refused to speak on nuclear energy because of his scepticism about it and gave a philosophical lecture instead.

During this period, Schrödinger turned from mainstream quantum mechanics' definition of wave–particle duality and promoted the wave idea alone, causing much controversy.

Tuberculosis and death

Annemarie and Erwin Schrödinger's gravesite; above the name plate Schrödinger's quantum mechanical wave equation is inscribed: Schrödinger suffered from tuberculosis and several times in the 1920s stayed at a sanatorium in Arosa.

It was there that he formulated his wave equation.

On 4 January 1961, Schrödinger died of tuberculosis, aged 73, in Vienna.

He left Anny a widow, and was buried in Alpbach, Austria, in a Catholic cemetery.

Although he was not Catholic, the priest in charge of the cemetery permitted the burial after learning Schrödinger was a member of the Pontifical Academy of Sciences.

Personal life

On 6 April 1920, Schrödinger married Annemarie (Anny) Bertel.

When he migrated to Ireland in 1938, he obtained visas for himself, his wife and also another woman, Hilde March.

March was the wife of an Austrian colleague and Schrödinger had fathered a daughter with her in 1934. Schrödinger wrote to the Taoiseach, Éamon de Valera personally, so as to obtain a visa for March.

In October 1939 the ménage à trois duly took up residence in Dublin. His wife, Anny (born 3 December 1896), died on 3 October 1965.

One of Schrödinger's grandchildren, Terry Rudolph, has followed in his footsteps as a quantum physicist, and teaches at Imperial College London.

Accusations of sexual abuse

Schrödinger kept a record of his sexual liaisons including children he sexually abused in a diary he called Ephemeridae, in which he stated a "predilection for teenage girls on the grounds that their innocence was the ideal match for his natural genius".

At the age of 39, Schrödinger tutored 14-year-old "Ithi" Junger. As John Gribbin recounted in his 2012 biography of Schrödinger, "As well as the maths, the lessons included 'a fair amount of

petting and cuddling' and Schrödinger soon convinced himself that he was in love with Ithi". Schrödinger assured Junger she wouldn't become pregnant, and seduced her at 17. She later became pregnant and had an abortion that left her sterile. Schrödinger left her soon after and moved on to other targets. Kate Nolan, a pseudonym used by surviving family to protect the victim, was also impregnated by Schrödinger amid claims of a lack of consent.

Carlo Rovelli notes in his book Helgoland that Schrödinger "always kept a number of relationships going at once – and made no secret of his fascination with preadolescent girls." In Ireland, Rovelli writes, he had one child each from two students identified in a Der Standard article as being a 26-year-old and a five-year-married political activist.

While carrying out research into a family tree, Bernard Biggar uncovered reports of Schrödinger grooming his cousin, Barbara MacEntee, when she was 12 years old. Apparently, her uncle, the mathematician and priest Pádraig de Brún, advised Schrödinger to no longer pursue her, and Schrödinger later wrote in his journal that she was one of his "unrequited loves".

MacEntee died in 1995, with the accounts emerging posthumously.

Walter Moore's biography of the scientist outlined that Schrödinger's attitude towards the women was "essentially that of a male supremacist", an assessment corroborated by Helge Kragh in his review of Moore's biography, the conquest of women, especially very young women, was the salt of life for this sincere romantic and male chauvinist.

Walter Moore used Schrödinger's relationships with girls to characterise what Moore called Schrödinger's "Lolita Complex".

Schrödinger's grandson and his mother were unhappy with the accusation made by Moore, and once the biography was published, their family broke off contact with him.

In a 2021 Irish Times article, Schrödinger's pattern of serial abuse was identified by the paper as a "behaviour [that] fitted the profile of a paedophile in the widely understood sense of that term." The physics department of Trinity College Dublin announced in January 2022 that they would recommend a lecture theatre that had been named for Schrödinger since the 1990s be renamed in light of his history of sexual abuse, while a picture of the scientist would be removed, and the renaming of an eponymous lecture series would be considered.

The College's webpage "The History of the School of Physics" currently has a photo labeled, "View of the front desk and blackboard at the Physics Lecture Theatre".

Academic interests and life of the mind

Early in his life, Schrödinger experimented in the fields of electrical engineering, atmospheric electricity, and atmospheric radioactivity, but he usually worked with his former teacher Franz Exner.

He also studied vibrational theory, the theory of Brownian motion, and mathematical statistics.

In 1912, at the request of the editors of the Handbook of Electricity and Magnetism, Schrödinger wrote an article titled Dielectrism.

That same year, Schrödinger gave a theoretical estimate of the probable height distribution of radioactive substances, which is required to explain the observed radioactivity of the atmosphere, and in August 1913 executed several experiments in Zeehame that confirmed his theoretical estimate and those of Victor Franz Hess.

For this work, Schrödinger was awarded the 1920 Haitinger Prize (Haitinger-Preis) of the Austrian Academy of Sciences. Other experimental studies conducted by the young researcher in 1914 were checking formulas for capillary pressure in gas bubbles and the study of the properties of soft beta radiation produced by gamma rays striking metal surface.

The last work he performed together with his friend Fritz Kohlrausch.

In 1919, Schrödinger performed his last physical experiment on coherent light and subsequently focused on theoretical studies.

Quantum mechanics: New quantum theory

In the first years of his career, Schrödinger became acquainted with the ideas of the old quantum theory, developed in the works of Max Planck, Albert Einstein, Niels Bohr, Arnold Sommerfeld, and others.

This knowledge helped him work on some problems in theoretical physics, but the Austrian scientist at the time was not yet ready to part with the traditional methods of classical physics.

Schrödinger's first publications about atomic theory and the theory of spectra began to emerge only from the beginning of

the 1920s, after his personal acquaintance with Sommerfeld and Wolfgang Pauli and his move to Germany.

In January 1921, Schrödinger finished his first article on this subject, about the framework of the Bohr-Sommerfeld effect of the interaction of electrons on some features of the spectra of the alkali metals. Of particular interest to him was the introduction of relativistic considerations in quantum theory.

In autumn 1922, he analyzed the electron orbits in an atom from a geometric point of view, using methods developed by the mathematician Hermann Weyl (1885–1955).

This work, in which it was shown that quantum orbits are associated with certain geometric properties, was an important step in predicting some of the features of wave mechanics. Earlier in the same year, he created the Schrödinger equation of the relativistic Doppler effect for spectral lines, based on the hypothesis of light quanta and considerations of energy and momentum.

He liked the idea of his teacher Exner on the statistical nature of the conservation laws, so he enthusiastically embraced the articles of Bohr, Kramers, and Slater, which suggested the possibility of violation of these laws in individual atomic processes (for example, in the process of emission of radiation). Although the experiments of Hans Geiger and Walther Bothe soon cast doubt on this, the idea of energy as a statistical concept was a lifelong attraction for Schrödinger, and he discussed it in some reports and publications.

Creation of wave mechanics

In January 1926, Schrödinger published in Annalen der Physik the paper "Quantisierung als Eigenwertproblem" (Quantization as an Eigenvalue Problem) on wave mechanics and presented what is now known as the Schrödinger equation.

In this paper, he gave a "derivation" of the wave equation for time-independent systems and showed that it gave the correct energy eigenvalues for a hydrogen-like atom.

This paper has been universally celebrated as one of the most important achievements of the twentieth century and created a revolution in most areas of quantum mechanics and indeed of all physics and chemistry.

A second paper was submitted just four weeks later that solved the quantum harmonic oscillator, rigid rotor, and diatomic molecule problems and gave a new derivation of the Schrödinger equation.

A third paper, published in May, showed the equivalence of his approach to that of Heisenberg and gave the treatment of the Stark effect. A fourth paper in this series showed how to treat problems in which the system changes with time, as in scattering problems.

In this paper, he introduced a complex solution to the wave equation in order to prevent the occurrence of fourth- and sixth-order differential equations. Schrödinger ultimately reduced the order of the equation to one.

(This was arguably the moment when quantum mechanics switched from real to complex numbers)

These papers were his central achievement and were at once recognized as having great significance by the physics community.

Schrödinger was not entirely comfortable with the implications of quantum theory referring to his theory as "wave mechanics". He wrote about the probability interpretation of quantum mechanics, saying, "I don't like it, and I'm sorry I ever had anything to do with it."

(Just in order to ridicule the Copenhagen interpretation of quantum mechanics, he contrived the famous thought experiment called Schrödinger's cat paradox and was said to have angrily complained to his students that "now the damned Gottingen physicists use my beautiful wave mechanics for calculating their shitty matrix elements).

Work on a unified field theory

Following his work on quantum mechanics, Schrödinger devoted considerable effort to working on a unified field theory that would unite gravity, electromagnetism, and nuclear forces within the basic framework of general relativity, doing the work with an extended correspondence with Albert Einstein.

In 1947, he announced a result, "Affine Field Theory", in a talk at the Royal Irish Academy, but the announcement was criticized by Einstein as "preliminary" and failed to lead to the desired unified theory.

Following the failure of his attempt at unification, Schrödinger gave up his work on unification and turned to other topics.

Interest in philosophy

Schrödinger had a deep interest in philosophy, and was influenced by the works of Arthur Schopenhauer and Baruch Spinoza. In his 1956 lecture "Mind and Matter", he said that "The world extended in space and time is but our representation. This is a repetition of the first words of Schopenhauer's main work.

Schopenhauer's works also introduced him to Indian philosophy, more specifically to the Upanishads and Advaita Vedanta's interpretation. He once took on a particular line of thought: "If the world is indeed created by our act of observation, there should be billions of such worlds, one for each of us.

How come your world and my world are the same? If something happens in my world, does it happen in your world, too? What causes all these worlds to synchronize with each other?".

"There is obviously only one alternative, namely the unification of minds or consciousnesses. Their multiplicity is only apparent, in truth there is only one mind. This is the doctrine of the Upanishads."

Schrödinger discussed topics such as consciousness, the mind-body problem, sense perception, free will, and objective reality in his lectures and writings.

Schrödinger's attitude with respect to the relations between Eastern and Western thought was one of prudence, expressing appreciation for Eastern philosophy while also admitting that some of the ideas did not fit with empirical approaches to natural philosophy.

Some commentators have suggested that Schrödinger was so deeply immersed in a non-dualist Vedântic-like view that it may have served as a broad framework or subliminal inspiration for much of his work including that in theoretical physics.

Schrödinger expressed sympathy for the idea of tat tvam asi, stating "you can throw yourself flat on the ground, stretched out upon Mother Earth, with the certain conviction that you are one with her and she with you." Schrödinger said that "Consciousness cannot be accounted for in physical terms.

For consciousness is absolutely fundamental. It cannot be accounted for in terms of anything else".

Legacy

The philosophical issues raised by Schrödinger's cat are still debated today and remain his most enduring legacy in popular science, while Schrödinger's equation is his most enduring legacy at a more technical level. Schrödinger is one of several individuals who have been called "the father of quantum mechanics".

The large crater Schrödinger, on the far side of the Moon, is named after him. The Erwin Schrödinger International Institute for Mathematical Physics was established in Vienna in 1993.

Schrödinger's portrait was the main feature of the design of the 1983–97 Austrian 1000-schilling banknote, the second-highest denomination.

A building is named after him at the University of Limerick, in Limerick, Ireland, as is the 'Erwin Schrödinger Zentrum' at

Adlershof in Berlin and the Route Schrödinger at CERN, Prévessin, France.

Schrödinger also has a lecture hall in Trinity College Dublin dedicated to him.

In January 2022, the head of the school of physics stated there would be a recommendation to drop Schrödinger lecture theatre name due to Schrödinger's "history of sexually abusing women and children".

Honors and awards

Erwin Schrödinger's Nobel Prize diploma.

Nobel Prize in Physics (1933) for the formulation of the Schrödinger equation, shared with Paul Dirac.

Max Planck Medal (1937).

Elected a Foreign Member of the Royal Society (ForMemRS) in 1949.

Erwin Schrödinger Prize of the Austrian Academy of Sciences (1956).

Austrian Decoration for Science and Art (1957). Schrödinger's cat is named in his honour.

About Wolfgang Pauli

Wolfgang Ernst Pauli; 25 April 1900 – 15 December 1958) was an Austrian theoretical physicist and one of the pioneers of quantum physics.

In 1945, after having been nominated by Albert Einstein, Pauli received the Nobel Prize in Physics for his "decisive

contribution through his discovery of a new law of Nature, the exclusion principle or Pauli principle". The discovery involved spin theory, which is the basis of a theory of the structure of matter.

Early years

Pauli was born in Vienna to a chemist, Wolfgang Joseph Pauli (né Wolf Pascheles, 1869–1955), and his wife, Bertha Camilla Schütz; his sister was Hertha Pauli, a writer and actress.

Pauli's middle name was given in honor of his godfather, physicist Ernst Mach. Pauli's paternal grandparents were from prominent Jewish families of Prague; his great-grandfather was the Jewish publisher Wolf Pascheles.

Pauli's mother, Bertha Schütz, was raised in her mother's Roman Catholic religion; her father was Jewish writer Friedrich Schütz. Pauli was raised as a Roman Catholic, although eventually he and his parents left the Church.

Pauli attended the Döblinger-Gymnasium in Vienna, graduating with distinction in 1918. Two months later, he published his first paper, on Albert Einstein's theory of general relativity.

He attended the Ludwig-Maximilians University in Munich, working under Arnold Sommerfeld, where he received his PhD in July 1921 for his thesis on the quantum theory of ionized diatomic hydrogen (H+2).

Career

Sommerfeld asked Pauli to review the theory of relativity for the Encyklopädie der mathematischen Wissenschaften (Encyclopedia of Mathematical Sciences). T

wo months after receiving his doctorate, Pauli completed the article, which came to 237 pages. Einstein praised it; published as a monograph, it remains a standard reference on the subject. Pauli spent a year at the University of Göttingen as the assistant to Max Born, and the next year at the Institute for Theoretical Physics in Copenhagen (later the Niels Bohr Institute).

From 1923 to 1928, he was a professor at the University of Hamburg. During this period, Pauli was instrumental in the development of the modern theory of quantum mechanics. In particular, he formulated the exclusion principle and the theory of nonrelativistic spin.

He also wrote a paper on colloid chemistry and medicine in 1924.

In 1928, Pauli was appointed Professor of Theoretical Physics at ETH Zurich in Switzerland.

He was awarded the Lorentz Medal in 1930. He held visiting professorships at the University of Michigan in 1931 and the Institute for Advanced Study in Princeton in 1935.

At the end of 1930, shortly after his postulation of the neutrino and immediately after his divorce and his mother's suicide, Pauli experienced a personal crisis.

In January 1932 he consulted psychiatrist and psychotherapist Carl Jung, who also lived near Zurich.

Jung immediately began interpreting Pauli's deeply archetypal dreams based on the I Ching, and Pauli became a collaborator of Jung's.

He soon began to critique the epistemology of Jung's theory scientifically, and this contributed to a certain clarification of Jung's ideas, especially about synchronicity.

A great many of these discussions are documented in the Pauli/Jung letters, today published as Atom and Archetype. Jung's elaborate analysis of more than 400 of Pauli's dreams is documented in Psychology and Alchemy.

In 1933 Pauli published the second part of his book on Physics, Handbuch der Physik, which was considered the definitive book on the new field of quantum physics. Robert Oppenheimer called it "the only adult introduction to quantum mechanics".

The German annexation of Austria in 1938 made Pauli a German citizen, which became a problem for him in 1939 after World War II broke out. In 1940, he tried in vain to obtain Swiss citizenship, which would have allowed him to remain at the ETH.

United States

In 1940, Pauli moved to the United States, where he was employed as a professor of theoretical physics at the Institute for Advanced Study. In 1946, after the war, he became a naturalized U.S. citizen and returned to Zurich, where he mostly remained for the rest of his life.

In 1949, he was granted Swiss citizenship.

In 1958, Pauli was awarded the Max Planck medal. The same year, he fell ill with pancreatic cancer.

When his last assistant, Charles Enz, visited him at the Rotkreuz hospital in Zurich, Pauli asked him, "Did you see the room number?"

It was 137.

Throughout his life, Pauli had been preoccupied with the question of why the fine-structure constant, a dimensionless fundamental constant, has a value nearly equal to 1/137. Pauli died in that room on 15 December 1958.

Scientific research

Pauli made many important contributions as a physicist, primarily in the field of quantum mechanics. He seldom published papers, preferring lengthy correspondences with colleagues such as Niels Bohr from the University of Copenhagen in Denmark and Werner Heisenberg, with whom he had close friendships.

Many of his ideas and results were never published and appeared only in his letters, which were often copied and circulated by their recipients.

In 1921 Pauli worked with Bohr to create the Aufbau Principle, which described building up electrons in shells based on the German word for building up, as Bohr was also fluent in German.

Pauli proposed in 1924 a new quantum degree of freedom (or quantum number) with two possible values, to resolve inconsistencies between observed molecular spectra and the developing theory of quantum mechanics.

He formulated the Pauli exclusion principle, perhaps his most important work, which stated that no two electrons could exist in the same quantum state, identified by four quantum numbers including his new two-valued degree of freedom.

The idea of spin originated with Ralph Kronig. A year later, George Uhlenbeck and Samuel Goudsmit identified Pauli's new degree of freedom as electron spin, in which Pauli for a very long time wrongly refused to believe.

In 1926, shortly after Heisenberg published the matrix theory of modern quantum mechanics, Pauli used it to derive the observed spectrum of the hydrogen atom. This result was important in securing credibility for Heisenberg's theory.

Pauli introduced the 2×2 Pauli matrices as a basis of spin operators, thus solving the nonrelativistic theory of spin. This work, including the Pauli equation, is sometimes said to have influenced Paul Dirac in his creation of the Dirac equation for the relativistic electron, though Dirac said that he invented these same matrices himself independently at the time.

Dirac invented similar but larger (4x4) spin matrices for use in his relativistic treatment of fermionic spin.

In 1930, Pauli considered the problem of beta decay. In a letter of 4 December to Lise Meitner et al., beginning, "Dear radioactive ladies and gentlemen", he proposed the existence of a hitherto unobserved neutral particle with a small mass, no greater than 1% the mass of a proton, to explain the continuous spectrum of beta decay.

In 1934, Enrico Fermi incorporated the particle, which he called a neutrino, "little neutral one" in Fermi's native Italian, into his theory of beta decay. The neutrino was first confirmed experimentally in 1956 by Frederick Reines and Clyde Cowan, two and a half years before Pauli's death. On receiving the news, he replied by telegram: "Thanks for message. Everything comes to him who knows how to wait. Pauli".

In 1940, Pauli re-derived the spin-statistics theorem, a critical result of quantum field theory that states that particles with half-integer spin are fermions, while particles with integer spin are bosons.

In 1949, he published a paper on Pauli–Villars regularization: regularization is the term for techniques that modify infinite mathematical integrals to make them finite during calculations, so that one can identify whether the intrinsically infinite quantities in the theory (mass, charge, wavefunction) form a finite and hence calculable set that can be redefined in terms of their experimental values, which criterion is termed renormalization, and which removes infinities from quantum field theories, but also importantly allows the calculation of higher-order corrections in perturbation theory.

Pauli made repeated criticisms of the modern synthesis of evolutionary biology, and his contemporary admirers point to modes of epigenetic inheritance as supporting his arguments. Paul Drude in 1900 proposed the first theoretical model for a classical electron moving through a metallic solid.

Drude's classical model was also augmented by Pauli and other physicists.

Pauli realized that the free electrons in metal must obey the Fermi–Dirac statistics. Using this idea, he developed the theory of paramagnetism in 1926. Pauli said, “Festkörperphysik ist eine Schmutzphysik”—solid-state physics is the physics of dirt.

Pauli was elected a Foreign Member of the Royal Society (ForMemRS) in 1953 and president of the Swiss Physical Society in 1955 for two years.

In 1958 he became a foreign member of the Royal Netherlands Academy of Arts and Sciences.

Personality and friendships

The Pauli effect was named after his anecdotal bizarre ability to break experimental equipment simply by being in its vicinity. Pauli was aware of his reputation and was delighted whenever the Pauli effect manifested.

These strange occurrences were in line with his controversial investigations into the legitimacy of parapsychology, particularly his collaboration with C. G. Jung on synchronicity. Max Born considered Pauli "only comparable to Einstein himself... perhaps even greater". Einstein declared Pauli his "spiritual heir".

Pauli was famously a perfectionist. This extended not just to his own work, but also to that of his colleagues. As a result, he became known in the physics community as the "conscience of physics", the critic to whom his colleagues were accountable.

He could be scathing in his dismissal of any theory he found lacking, often labelling it ganz falsch, "utterly wrong".

But this was not his most severe criticism, which he reserved for theories or theses so unclearly presented as to be untestable or unevaluatable and thus not properly belonging within the realm of science, even though posing as such.

They were worse than wrong because they could not be proved wrong.

Famously, he once said of such an unclear paper: "It is not even wrong!"

His supposed remark when meeting another leading physicist, Paul Ehrenfest, illustrates this notion of an arrogant Pauli. The two met at a conference for the first time. Ehrenfest was familiar with Pauli's papers and quite impressed with them.

After a few minutes of conversation, Ehrenfest remarked, "I think I like your Encyclopedia article [on relativity theory] better than I like you," to which Pauli retorted, "That's strange. With me, regarding you, it is just the opposite." The two became very good friends from then on.

A somewhat warmer picture emerges from this story, which appears in the article on Dirac: Werner Heisenberg [in Physics and Beyond, 1971] recollects a friendly conversation among young participants at the 1927 Solvay Conference, about Einstein and Planck's views on religion.

Wolfgang Pauli, Heisenberg, and Dirac took part in it. Dirac's contribution was a poignant and clear criticism of the political manipulation of religion, that was much appreciated for its lucidity by Bohr, when Heisenberg reported it to him later.

Among other things, Dirac said: "I cannot understand why we idle discussing religion. If we are honest – and as scientist’s honesty is our precise duty – we cannot help but admit that any religion is a pack of false statements, deprived of any real foundation.

The very idea of God is a product of human imagination. I do not recognize any religious myth, at least because they contradict one another. " Heisenberg's view was tolerant. Pauli had kept silent, after some initial remarks. But when finally, he was asked for his opinion, jokingly he said: "Well, I'd say that also our friend Dirac has got a religion and the first commandment of this religion is 'God does not exist and Paul Dirac is his prophet'".

Everybody burst into laughter, including Dirac.

Many of Pauli's ideas and results were never published and appeared only in his letters, which were often copied and circulated by their recipients.

Pauli may have been unconcerned that much of his work thus went uncredited, but when it came to Heisenberg's world-renowned 1958 lecture at Göttingen on their joint work on a unified field theory, and the press release calling Pauli a mere "assistant to Professor Heisenberg", Pauli became offended, denouncing Heisenberg's physics prowess.

The deterioration of their relationship resulted in Heisenberg ignoring Pauli's funeral, and writing in his autobiography that Pauli's criticisms were overwrought, though ultimately the field theory was proved untenable, validating Pauli's criticisms.

Philosophy

In his discussions with Carl Jung, Pauli developed an ontological theory that has been dubbed the "Pauli–Jung Conjecture" and has been seen a kind of dual-aspect theory.

The theory holds that there is "a psychophysically neutral reality" and that mental and physical aspects are derivative of this reality.

Pauli thought that elements of quantum physics pointed to a deeper reality that might explain the mind/matter gap and wrote, "we must postulate a cosmic order of nature beyond our control to which both the outward material objects and the inward images are subject".

Pauli and Jung held that this reality was governed by common principles ("archetypes") that appear as psychological phenomena or as physical events. They also held that synchronicities might reveal some of this underlying reality's workings.

Beliefs

He is considered to have been a deist and a mystic. In No Time to Be Brief: A Scientific Biography of Wolfgang Pauli he is quoted as writing to science historian Shmuel Sambursky, "In opposition to the monotheist religions – but in unison with the mysticism of all peoples, including the Jewish mysticism – I believe that the ultimate reality is not personal".

Personal life

Bust of Wolfgang Pauli (1962)

In 1929, Pauli married Käthe Margarethe Deppner, a cabaret dancer. The marriage was unhappy, ending in divorce after less than a year.

He married again in 1934 to Franziska Bertram (1901–1987). They had no children.

Death

Pauli died of pancreatic cancer on December 15, 1958, at age 58.

About Archimedes of Syracuse

Archimedes of Syracuse (c. 287 – c. 212 BC) was a Greek mathematician, physicist, engineer, astronomer, and inventor from the ancient city of Syracuse in Sicily.

Although few details of his life are known, he is regarded as one of the leading scientists in classical antiquity.

Considered the greatest mathematician of ancient history, and one of the greatest of all time, Archimedes anticipated modern calculus and analysis by applying the concept of the infinitely small and the method of exhaustion to derive and rigorously prove a range of geometrical theorems.

These include the area of a circle, the surface area and volume of a sphere, the area of an ellipse, the area under a parabola, the volume of a segment of a paraboloid of revolution, the volume of a segment of a hyperboloid of revolution, and the area of a spiral.

Archimedes' other mathematical achievements include deriving an approximation of pi, defining and investigating the

Archimedean spiral, and devising a system using exponentiation for expressing very large numbers.

He was also one of the first to apply mathematics to physical phenomena, working on statics and hydrostatics. Archimedes' achievements in this area include a proof of the law of the lever, the widespread use of the concept of center of gravity, and the enunciation of the law of buoyancy or Archimedes' principle.

He is also credited with designing innovative machines, such as his screw pump, compound pulleys, and defensive war machines to protect his native Syracuse from invasion. Archimedes died during the siege of Syracuse, when he was killed by a Roman soldier despite orders that he should not be harmed.

Cicero describes visiting Archimedes' tomb, which was surmounted by a sphere and a cylinder that Archimedes requested be placed there to represent his mathematical discoveries.

Unlike his inventions, Archimedes' mathematical writings were little known in antiquity. Mathematicians from Alexandria read and quoted him, but the first comprehensive compilation was not made until c. 530 AD by Isidore of Miletus in Byzantine Constantinople, while commentaries on the works of Archimedes by Eutocius in the 6th century opened them to wider readership for the first time.

The relatively few copies of Archimedes' written work that survived through the Middle Ages were an influential source of ideas for scientists during the Renaissance and again in the

17th century, while the discovery in 1906 of previously lost works by Archimedes in the Archimedes Palimpsest has provided new insights into how he obtained mathematical results.

Biography

Archimedes was born c. 287 BC in the seaport city of Syracuse, Sicily, at that time a self-governing colony in Magna Graecia. The date of birth is based on a statement by the Byzantine Greek historian John Tzetzes that Archimedes lived for 75 years before his death in 212 BC.

In the Sand-Reckoner, Archimedes gives his father's name as Phidias, an astronomer about whom nothing else is known. A biography of Archimedes was written by his friend Heracleides, but this work has been lost, leaving the details of his life obscure. It is unknown, for instance, whether he ever married or had children, or if he ever visited Alexandria, Egypt, during his youth.

From his surviving written works, it is clear that he maintained collegiate relations with scholars based there, including his friend Conon of Samos and the head librarian Eratosthenes of Cyrene.

The standard versions of Archimedes' life were written long after his death by Greek and Roman historians. The earliest reference to Archimedes occurs in The Histories by Polybius (c. 200–118 BC), written about 70 years after his death. It sheds little light on Archimedes as a person, and focuses on the war machines that he is said to have built in order to defend the city from the Romans.

Polybius remarks how, during the Second Punic War, Syracuse switched allegiances from Rome to Carthage, resulting in a military campaign under the command of Marcus Claudius Marcellus and Appius Claudius Pulcher, who besieged the city from 213 to 212 BC.

He notes that the Romans underestimated Syracuse's defenses, and mentions several machines Archimedes designed, including improved catapults, crane-like machines that could be swung around in an arc, and other stone-throwers.

Although the Romans ultimately captured the city, they suffered considerable losses due to Archimedes' inventiveness.

Cicero (106–43 BC) mentions Archimedes in some of his works. While serving as a quaestor in Sicily, Cicero found what was presumed to be Archimedes' tomb near the Agrigentine gate in Syracuse, in a neglected condition and overgrown with bushes.

Cicero had the tomb cleaned up and was able to see the carving and read some of the verses that had been added as an inscription. The tomb carried a sculpture illustrating Archimedes' favorite mathematical proof, that the volume and surface area of the sphere are two-thirds that of an enclosing cylinder including its bases.

He also mentions that Marcellus brought to Rome two planetariums Archimedes built.

The Roman historian Livy (59 BC–17 AD) retells Polybius' story of the capture of Syracuse and Archimedes' role in it.

Plutarch (45–119 AD) wrote in his Parallel Lives that Archimedes was related to King Hiero II, the ruler of Syracuse.

He also provides at least two accounts on how Archimedes died after the city was taken. According to the most popular account, Archimedes was contemplating a mathematical diagram when the city was captured. A Roman soldier commanded him to come and meet Marcellus, but he declined, saying that he had to finish working on the problem.

This enraged the soldier, who killed Archimedes with his sword. Another story has Archimedes carrying mathematical instruments before being killed because a soldier thought they were valuable items.

Marcellus was reportedly angered by Archimedes' death, as he considered him a valuable scientific asset (he called Archimedes "a geometrical Briareus") and had ordered that he should not be harmed. The last words attributed to Archimedes are "Do not disturb my circles" (Latin, "Noli turbare circulos meos), a reference to the mathematical drawing that he was supposedly studying when disturbed by the Roman soldier.

There is no reliable evidence that Archimedes uttered these words and they do not appear in Plutarch's account. A similar quotation is found in the work of Valerius Maximus (fl. 30 AD), who wrote in Memorable Doings and Sayings, "... sed protecto manibus puluere 'noli' inquit, 'obsecro, istum disturbare'" ("... but protecting the dust with his hands, said 'I beg of you, do not disturb this'").

Discoveries and inventions: Archimedes' principle

The most widely known anecdote about Archimedes tells of how he invented a method for determining the volume of an object with an irregular shape.

According to Vitruvius, a votive crown for a temple had been made for King Hiero II of Syracuse, who had supplied the pure gold to be used; Archimedes was asked to determine whether some silver had been substituted by the dishonest goldsmith.

Archimedes had to solve the problem without damaging the crown, so he could not melt it down into a regularly shaped body in order to calculate its density.

In Vitruvius' account, Archimedes noticed while taking a bath that the level of the water in the tub rose as he got in, and realized that this effect could be used to determine the crown's volume.

For practical purposes water is incompressible, so the submerged crown would displace an amount of water equal to its own volume. By dividing the mass of the crown by the volume of water displaced, the density of the crown could be obtained.

This density would be lower than that of gold if cheaper and less dense metals had been added. Archimedes then took to the streets naked, so excited by his discovery that he had forgotten to dress, crying "Eureka!".

The test on the crown was conducted successfully, proving that silver had indeed been mixed in.

The story of the golden crown does not appear anywhere in Archimedes' known works. The practicality of the method it describes has been called into question due to the extreme accuracy that would be required while measuring the water displacement.

Archimedes may have instead sought a solution that applied the principle known in hydrostatics as Archimedes' principle, which he describes in his treatise On Floating Bodies.

This principle states that a body immersed in a fluid experiences a buoyant force equal to the weight of the fluid it displaces. Using this principle, it would have been possible to compare the density of the crown to that of pure gold by balancing the crown on a scale with a pure gold reference sample of the same weight, then immersing the apparatus in water.

The difference in density between the two samples would cause the scale to tip accordingly. Galileo Galilei, who in 1586 invented a hydrostatic balance for weighing metals in air and water inspired by the work of Archimedes, considered it "probable that this method is the same that Archimedes followed, since, besides being very accurate, it is based on demonstrations found by Archimedes himself".

Archimedes' screw

A large part of Archimedes' work in engineering probably arose from fulfilling the needs of his home city of Syracuse. Athenaeus of Naucratis quotes a certain Moschion in a description on how King Hiero II commissioned the design of a huge ship, the Syracusia, which could be used for luxury travel, carrying supplies, and as a display of naval power.

The Syracusia is said to have been the largest ship built in classical antiquity and, according to Athenaeus' account, it was launched by Archimedes.

The ship presumably was capable of carrying 600 people and included garden decorations, a gymnasium, and a temple dedicated to the goddess Aphrodite among its facilities.

The account also mentions that, in order to remove any potential water leaking through the hull, a device with a revolving screw-shaped blade inside a cylinder was designed by Archimedes.

Archimedes' screw was turned by hand, and could also be used to transfer water from a low-lying body of water into irrigation canals. The screw is still in use today for pumping liquids and granulated solids such as coal and grain.

Described by Vitruvius, Archimedes' device may have been an improvement on a screw pump that was used to irrigate the Hanging Gardens of Babylon. The world's first seagoing steamship with a screw propeller was the SS Archimedes, which was launched in 1839 and named in honor of Archimedes and his work on the screw.

Archimedes' claw

Archimedes is said to have designed a claw as a weapon to defend the city of Syracuse.

Also known as "the ship shaker", the claw consisted of a crane-like arm from which a large metal grappling hook was suspended.

When the claw was dropped onto an attacking ship the arm would swing upwards, lifting the ship out of the water and possibly sinking it.

There have been modern experiments to test the feasibility of the claw, and in 2005 a television documentary entitled Superweapons of the Ancient World built a version of the claw and concluded that it was a workable device.

Heat ray

Archimedes may have written a work on mirrors entitled Catoptrica, and later authors believed he might have used mirrors acting collectively as a parabolic reflector to burn ships attacking Syracuse.

Lucian wrote, in the second century AD, that during the siege of Syracuse Archimedes destroyed enemy ships with fire. Almost four hundred years later, Anthemius of Tralles mentions, somewhat hesitantly, that Archimedes could have used burning-glasses as a weapon.

The presumed device, often called the "Archimedes heat ray", focused sunlight onto approaching ships, causing them to catch fire. In the modern era, similar devices have been constructed and may be referred to as a heliostat or solar furnace. Archimedes' purported heat ray has been the subject of an ongoing debate about its credibility since the Renaissance. René Descartes rejected it as false, while modern researchers have attempted to recreate the effect using only the means that would have been available to Archimedes, mostly with negative results.

It has been suggested that a large array of highly polished bronze or copper shields acting as mirrors could have been employed to focus sunlight onto a ship, but the overall effect

would have been blinding, dazzling, or distracting the crew of the ship rather than fire.

Lever

While Archimedes did not invent the lever, he gave a mathematical proof of the principle involved in his work On the Equilibrium of Planes. Earlier descriptions of the lever are found in the Peripatetic school of the followers of Aristotle, and are sometimes attributed to Archytas.

There are several, often conflicting, reports regarding Archimedes' feats using the lever to lift very heavy objects. Plutarch describes how Archimedes designed block-and-tackle pulley systems, allowing sailors to use the principle of leverage to lift objects that would otherwise have been too heavy to move. According to Pappus of Alexandria, Archimedes' work on levers caused him to remark: "Give me a place to stand on, and I will move the Earth".

Olympiodorus later attributed the same boast to Archimedes' invention of the baroulkos, a kind of windlass, rather than the lever. Archimedes has also been credited with improving the power and accuracy of the catapult, and with inventing the odometer during the First Punic War.

The odometer was described as a cart with a gear mechanism that dropped a ball into a container after each mile traveled.

Astronomical instruments

Archimedes discusses astronomical measurements of the Earth, Sun, and Moon, as well as Aristarchus' heliocentric model of the universe, in the Sand-Reckoner.

Without the use of either trigonometry or a table of chords, Archimedes describes the procedure and instrument used to make observations (a straight rod with pegs or grooves), applies correction factors to these measurements, and finally gives the result in the form of upper and lower bounds to account for observational error.

Ptolemy, quoting Hipparchus, also references Archimedes' solstice observations in the Almagest. This would make Archimedes the first known Greek to have recorded multiple solstice dates and times in successive years.

Cicero's De re publica portrays a fictional conversation taking place in 129 BC, after the Second Punic War. General Marcus Claudius Marcellus is said to have taken back to Rome two mechanisms after capturing Syracuse in 212 BC, which were constructed by Archimedes and which showed the motion of the Sun, Moon and five planets.

Cicero also mentions similar mechanisms designed by Thales of Miletus and Eudoxus of Cnidus.

The dialogue says that Marcellus kept one of the devices as his only personal loot from Syracuse, and donated the other to the Temple of Virtue in Rome. Marcellus' mechanism was demonstrated, according to Cicero, by Gaius Sulpicius Gallus to Lucius Furius Philus, who described it thus: When Gallus moved the globe, it happened that the Moon followed the Sun by as many turns on that bronze contrivance as in the sky itself, from which also in the sky the Sun's globe became to have that same eclipse, and the Moon came then to that position which was its shadow on the Earth when the Sun was in line.

This is a description of a small planetarium.

Pappus of Alexandria reports on a treatise by Archimedes (now lost) dealing with the construction of these mechanisms entitled On Sphere-Making. Modern research in this area has been focused on the Antikythera mechanism, another device built c. 100 BC that was probably designed for the same purpose. Constructing mechanisms of this kind would have required a sophisticated knowledge of differential gearing.

This was once thought to have been beyond the range of the technology available in ancient times, but the discovery of the Antikythera mechanism in 1902 has confirmed that devices of this kind were known to the ancient Greeks.

Mathematics

While he is often regarded as a designer of mechanical devices, Archimedes also made contributions to the field of mathematics.

Plutarch wrote that Archimedes "placed his whole affection and ambition in those purer speculations where there can be no reference to the vulgar needs of life", though some scholars believe this may be a mischaracterization.

Method of exhaustion

Archimedes was able to use indivisibles (a precursor to infinitesimals) in a way that is similar to modern integral calculus. Through proof by contradiction (reductio ad absurdum), he could give answers to problems to an arbitrary degree of accuracy, while specifying the limits within which the answer lay.

This technique is known as the method of exhaustion, and he employed it to approximate the areas of figures and the value of π.

In Measurement of a Circle, he did this by drawing a larger regular hexagon outside a circle then a smaller regular hexagon inside the circle, and progressively doubling the number of sides of each regular polygon, calculating the length of a side of each polygon at each step. As the number of sides increases, it becomes a more accurate approximation of a circle.

After four such steps, when the polygons had 96 sides each, he was able to determine that the value of π lay between 3 (approx. 3.1408), consistent with its actual value of approximately 3.1416.

He also proved that the area of a circle was equal to π multiplied by the square of the radius of the circle.

Writings

The works of Archimedes were written in Doric Greek, the dialect of ancient Syracuse. Many written works by Archimedes have not survived or are only extant in heavily edited fragments; at least seven of his treatises are known to have existed due to references made by other authors.

Pappus of Alexandria mentions On Sphere-Making and another work on polyhedra, while Theon of Alexandria quotes a remark about refraction from the now-lost Catoptrica.

Archimedes made his work known through correspondence with the mathematicians in Alexandria.

The writings of Archimedes were first collected by the Byzantine Greek architect Isidore of Miletus (c. 530 AD), while commentaries on the works of Archimedes written by Eutocius in the sixth century AD helped to bring his work a wider audience.

Archimedes' work was translated into Arabic by Thābit ibn Qurra (836–901 AD), and into Latin via Arabic by Gerard of Cremona (c. 1114–1187).

Direct Greek to Latin translations were later done by William of Moerbeke (c. 1215–1286) and Iacobus Cremonensis (c. 1400–1453).

During the Renaissance, the Editio princeps (First Edition) was published in Basel in 1544 by Johann Herwagen with the works of Archimedes in Greek and Latin.

Archimedes Palimpsest

The foremost document containing Archimedes' work is the Archimedes Palimpsest.

In 1906, the Danish Professor Johan Ludvig Heiberg visited Constantinople to examine a 174-page goatskin parchment of prayers, written in the 13th century, after reading a short transcription published seven years earlier by Papadopoulos-Kerameus.

He confirmed that it was indeed a palimpsest, a document with text that had been written over an erased older work. Palimpsests were created by scraping the ink from existing works and reusing them, a common practice in the Middle Ages, as vellum was expensive.

The older works in the palimpsest were identified by scholars as 10th-century copies of previously lost treatises by Archimedes.

The parchment spent hundreds of years in a monastery library in Constantinople before being sold to a private collector in the 1920s.

On 29 October 1998, it was sold at auction to an anonymous buyer for $2 million.

The palimpsest holds seven treatises, including the only surviving copy of On Floating Bodies in the original Greek. It is the only known source of The Method of Mechanical Theorems, referred to by Suidas and thought to have been lost forever. Stomachion was also discovered in the palimpsest, with a more complete analysis of the puzzle than had been found in previous texts.

The palimpsest was stored at the Walters Art Museum in Baltimore, Maryland, where it was subjected to a range of modern tests including the use of ultraviolet and X-ray light to read the overwritten text.

It has since returned to its anonymous owner.

Mathematics and physics

Historians of science and mathematics almost universally agree that Archimedes was the finest mathematician from antiquity. Eric Temple Bell, for instance, wrote: Any list of the three “greatest” mathematicians of all history would include the name of Archimedes. The other two usually associated with him are Newton and Gauss.

Some, considering the relative wealth—or poverty—of mathematics and physical science in the respective ages in which these giants lived, and estimating their achievements against the background of their times, would put Archimedes first.

Likewise, Alfred North Whitehead and George F. Simmons said of Archimedes: ... in the year 1500 Europe knew less than Archimedes who died in the year 212 BC ...

If we consider what all other men accomplished in mathematics and physics, on every continent and in every civilization, from the beginning of time down to the seventeenth century in Western Europe, the achievements of Archimedes outweigh it all.

He was a great civilization all by himself.

Reviel Netz, Suppes Professor in Greek Mathematics and Astronomy at Stanford University and an expert in Archimedes notes: And so, since Archimedes led more than anyone else to the formation of the calculus and since he was the pioneer of the application of mathematics to the physical world, it turns out that Western science is but a series of footnotes to Archimedes.

Thus, it turns out that Archimedes is the most important scientist who ever lived. Leonardo da Vinci repeatedly expressed admiration for Archimedes, and attributed his invention Architonnerre to Archimedes.

Galileo called him "superhuman" and "my master", while Huygens said, "I think Archimedes is comparable to no one",

and modeled his work after him. Leibniz said, "He who understands Archimedes and Apollonius will admire less the achievements of the foremost men of later times".

Gauss's heroes were Archimedes and Newton, and Moritz Cantor, who studied under Gauss in the University of Göttingen, reported that he once remarked in conversation that "there had been only three epoch-making mathematicians: Archimedes, Newton, and Eisenstein".

Honors and commemorations:

There is a crater on the Moon named Archimedes (29.7° N 4.0° W) in his honor, as well as a lunar mountain range, the Montes Archimedes (25.3° N 4.6° W).

The Fields Medal for outstanding achievement in mathematics carries a portrait of Archimedes, along with a carving illustrating his proof on the sphere and the cylinder. The inscription around the head of Archimedes is a quote attributed to 1st century AD poet Manilius, which reads in Latin: Transire suum pectus mundoque potiri ("Rise above oneself and grasp the world").

Archimedes has appeared on postage stamps issued by East Germany (1973), Greece (1983), Italy (1983), Nicaragua (1971), San Marino (1982), and Spain (1963).

The exclamation of Eureka! attributed to Archimedes is the state motto of California.

In this instance, the word refers to the discovery of gold near Sutter's Mill in 1848 which sparked the California Gold Rush.